Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Instrumentation's Unity

ONE fine day when you were a young lad, you saw that the cherries were ripening, so you whistled to your big brother to c'mon over, then he shook a tree to make the ripe cherries drop. In other words, you produced airborne vibrations (frequencies 1000-4000 per second with a glissando effect) then he produced flexural vibrations of about half-second frequency in a solid. Neither of you, of course, would have put it that way, but if your science teacher had been passing by, he might have pointed out the functional resemblance between generating sound waves in the air and generating oscillations in a tree trunk.

Since becoming an *Instruments* reader, however, you no doubt have noticed functional resemblances between instruments serving widely different practical purposes. Sometimes, two different-but-essentially-similar instruments have been reported in the same issue. Your editor gets as much of a kick as you do when such coincidences occur and (don't tell anybody!) we have even taken delight in dramatizing similarities.

Once—and once only—we received within a few days the announcements of *three* apparently-different but functionally-similar new devices: a chemical pump, a pre-set gasoline meter and a granular-material dispenser. That was in December 1935. If you were a subscriber then you may remember that on page 25 of the January 1936 issue three headings were worded almost alike:

Automatic Continuous Volumeter-feeder	Automatic Intermittent Volumeter-feeder	Automatic Continuous Weigher-feeder

and that the opening sentences were constructed similarly, only the characteristic words and figures being different.

Don't look now but there's one of those pairs of items in this issue . . . yes, on the next page. One photograph shows a radio-like instrument; the other shows heavy machinery on a shop floor. The first apparatus produces supersonic waves in liquids to determine emulsification properties, etc.; the second shakes machine parts to determine stress-reversal properties, etc. At first glance, their resemblance seems far-fetched—like a phonograph and a rock drill. Both have exactly the same function, however: to convert electrical energy into mechanical vibrations, the main difference being in the frequency ranges. But isn't there an enormous difference in power? No: the "console" model of the radio-like device delivers more horsepower than does the medium-size model of the machinery shaker. Such whistle could the cherries *vernichtungschlagen!*

Not only does Instrumentation make possible the fascinating marvels of chemistry, aviation, etc., but it is a fascinating study in itself—even when you only study the new products and the new methods.

THIS is an "Editorial":

420 East Third Street
National City, Calif.

To the Editor of Instruments:

I have just read your very interesting editorial comment in the February issue of *Instruments*, which to my way of thinking is a step forward in the right direction. Your article on the "Fast-growing Need for Education and Training" makes interesting and constructive reading. I can appreciate this need perhaps more than the average person because I am an instrument man with thirty-two years of experience with various instruments, timing devices, time switches and clocks. I have had twelve years' factory experience in the manufacture of instruments and twenty years' experience in care and maintenance. I know what the problem is when it comes to the need for skilled instrument mechanics; this is specialized work and it calls for specialized training. I served a five-year apprenticeship to Instrument making and Horology in England and I have found this very much to my advantage in obtaining employment in America. For years I have seen the need for men trained in this kind of work steadily growing, but unfortunately the trained men were not available. This condition was partly brought about by the enormous increase in the demands for instruments of all types during the last fifteen years. More and more the call is for instruments, which in turn will call for men to make them and others to do the work of care and maintenance. To properly train men to do this kind of work requires highly-specialized training with practical and personal instruction. I might also add that it requires a more or less special kind of individual, certainly one who possesses plenty of patience, perseverance, ingenuity, a keen sense of touch and proportions, and above all, natural ability and interest in small mechanical devices.

You are right when you say the "bottleneck" exists in training and practical experience, and not so much in education; I have had men work with me who had education; but that is all they did have. When it comes to manipulations and coordination between the mind and hands they were lost. After all, the great need is for men skilled in a practical sense, those who can do things with their hands. A soldier may read a book on how to manipulate his rifle, but it takes a sergeant on the drill grounds to give him practical and beneficial instruction in the proper manipulation. You mention the formulation of a book on the care and maintenance of instruments. If such a book were obtainable I certainly would appreciate having one.

I have been reading *Instruments* for twelve years. Where I am employed it is circulated from our library around to the various departments and quite often it is two or three months after issue before I get my look at it. To say the least I am fed up with this delay, so I am sending you a year's subscription for *Instruments* and I would also like to get January and February issues. I am also sending for the handbook of airplane instruments by Kollsman that you describe. I enjoy having books that have some connection with my trade. After I have seen the Kollsman book I may be able to advise you on the comparative usefulness of other text books. I have taught others my trade and they have become competent craftsmen; as for book knowledge it has helped considerable. However, my experience has convinced me that first of all a student or apprentice must be shown the various tools and how to use them, also the various pieces and parts that go to make up the apparatus, their names and characteristics; in other words, become acquainted with the things he is going to read about so that he understands what he is reading. He must do the work himself to get practical experience, and the so-called "tricks-of-the-trade" are generally imparted to him by those who have gained the necessary knowledge from craftsmen who have gone before, plus their years of practical experience. There is considerable information that could be written on this subject, but I am wondering if I have not already taken too much liberty with you. Your editorial is on a subject that I am very much interested in, so please forgive me. I would be glad to hear from you and if I can be of any help in giving training or information I shall be glad to cooperate.

March 31, 1941 — Albert E. Clark.

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Measures Capacity, Power Factor, Phase Angle, Resistance, Inductance and Frequency. Indicates Synchronism. Null system employed to indicate bridge balance, same as in conventional D.C. bridge. Invaluable for use in schools, laboratories, and inspection departments.

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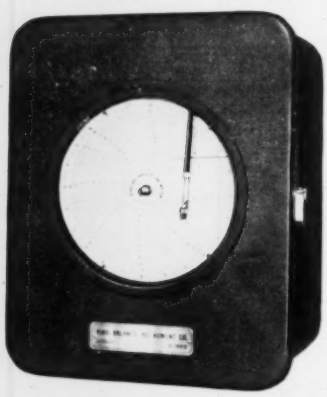

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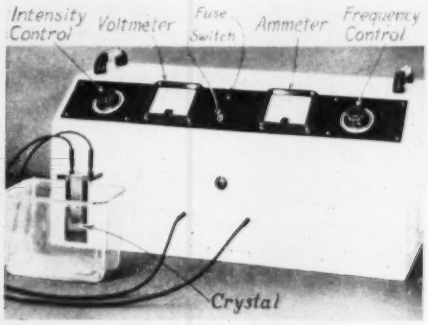
THE MONTH'S NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control.

When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Ultrasonic Energy Generators

Announcement is made of the first commercially-available line of ultrasonic energy generators. Manufacturer is the firm which in 1937 had built several semi-commercial units for universities and for the plastics industry. Units now announced, designated "Ultrason," are said to be fully-developed, ready-to-use and as stable as high-grade radio apparatus in their frequency and other characteristics. All employ



the oscillatory-circuit and piezoelectric-crystal method of production and have frequency ranges suitable for work between 100 and 700 kc. with higher frequencies (up to 2 Mc.) possible. Unit illustrated is "Ultrason Model 56" of 215-watt power, producing 80 watts of ultrasonic energy at 400 kc.; dimensions 30" × 15" × 13"; weight 100 lbs. "Model 57" has the same dimensions but more power (251 watts at 400 kc.) and weighs 136 lbs. "Model 58" is a cabinet apparatus with power supplies in lower cabinet which is provided with casters for moving; it can produce 596 watts at 400 kc. "Model 59" is largest (5 ft. high) and most powerful (1600 watts at 400 kc.)—*Televisa Products, Inc., 2400 N. Sheffield Ave., Chicago, Ill.*

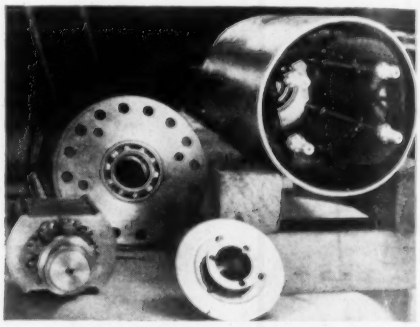
Electrical Tachometer

New a-c. tachometer comprises (1) a non-sparking transmitter which is a brushless

and commutatorless generator, (2) a rectifier and (3) a receiver which is a d-c. instrument graduated in r.p.m., g.p.m. or other units of speed, of fluid flow, etc.—*Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.*

Vibration Energy Generators and Related Equipment

For study and control of vibration, high-powered linear and torsional vibration generators, special torsional pickups, and high-power amplifiers and power sources, are announced. Integrated installations are maker's specialty. Illustration shows a special torsional vibration generator said to be the largest ever built. It will put more than 30 hp. of reactive energy into the structure under test. By using vibration generators to drive test specimens at their resonant frequencies, fatigue tests can be run at rates as high as 10,000 reversals per second, with precise control of stress, making it possible to run one hundred million stress reversals in about three hours for quick tests on steel samples.—*Andrews & Perilla Inc., 35-49 Crescent St., Long Island City, N. Y.*



Time Switch

New "300 Series" is said to be the only time switch made with just two exposed gears. (the other gears operate in a sealed oil bath and consequently are always lubri-

cated). Operation is not affected by dust. is accomplished by slow-speed (450 r.p.m.) industrial type self-starting synchronous motor. For actuating off-tripper there is a reserve power of 40 lbs. or an equivalent of 2000%. Switch is said to operate successfully at —20°F.—*Paragon Electric Co., 37 W. Van Buren St., Chicago, Ill.*

IMPROVED "SPOTLIGHTS"

Rubicon MULTIPLE REFLECTION galvanometers have recently been much improved through redesign of optical system. The definition of the line-image is now so sharp that readings can be estimated to .1 of a millimeter division.

These sturdy self-contained galvanometers are available with sensitivities as high as 5×10^{-10} ampere and 1×10^{-6} volt per millimeter division.

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Write for Bulletin #T-103

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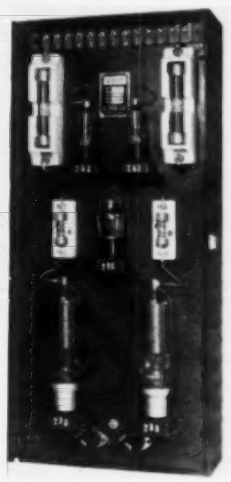
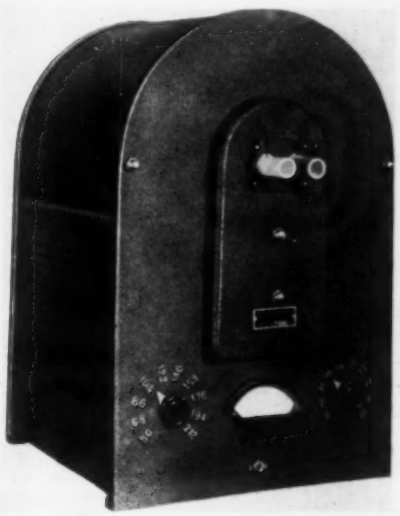
Welding Synchronizer

"Weltronic Synchronizer" is a new type of unit for precision control in resistance-welding work. It is designed to be used with any non-synchronous timer and power-tube contactor to obtain synchronous operation, by which is meant starting current flow at the zero point on the current wave, provided wave-form is approximately sinusoidal. This eliminates the presence of transient currents and the resulting stresses and strains caused by these transients in welding transformers, making for longer transformer life and in some instances allowing the use of smaller-size transformers. It is said that "uniform perfect welds" result from the use of new Synchronizer with non-synchronous timing devices. Dust-proof steel cabinet is approx. 30" × 12" × 12" for wall mounting and is easily wired to any existing non-synchronous timer. Since it obviates need of firing relay usually supplied with power tube contactors, it provides for absolute accuracy in timing, even at a rate of operation as high as 1000 welds per minute, it is said. Device has an adjustment for any value of power factor encountered in welding transformers.—*The Weltronic Corp., 3080 E. Outer Drive, Detroit, Mich.*



Two-tube Combustion Furnace

A two-tube "Varitemp" combustion furnace now supplements maker's single-tube model (*Instruments*, July 1940, page 1741). Furnace front forms a switchboard on



which are mounted the pyrometer indicator, electric switch and two selective switches for selection of the proper voltage to maintain a chosen temperature. Maximum temperature is 2750° F. Four Globar heating elements (Carborundum Co.) are used to heat the two combustion tubes uniformly. All electrical parts are enclosed in a compartment in lower ventilated portion. Furnace is well insulated to prevent excessive heat loss into the room.—*Harry W. Dietert Co., 9339 Roselawn Ave., Detroit, Mich.*

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Effective Control

Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

Thermocouple Checking Furnace

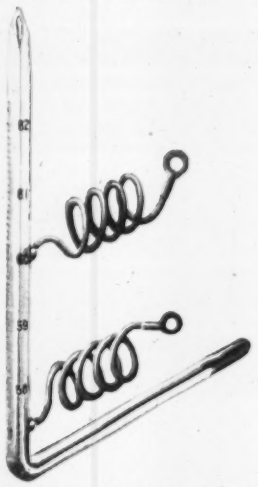
Thermocouples may be checked to greater accuracy and over a wider temperature range in maker's redesigned Checking Furnace. New equipment is a small electric furnace which provides a zone of "practically uniform" temperature for intercomparison of laboratory standard couples and for comparison of laboratory standard and plant standard couples. A new accessory which increases accuracy of checking is a cylindrical copper equalizing block that fits inside the furnace. Drilled into this block are five wells to hold the comparison standard and the four couples being checked. With the equalizing block, checks can be made within ±1°F. from room temperature up to 1600°F. Without it, checks can be made within ±3°F. over a range of 300 to 1800°F. Available with heating elements for either a-c. or d-c. operation on 115 or 230 volts, this furnace requires an input ranging from 40 watts at 300°F. up to 1800°F. When temperature must be raised rapidly, input can be increased to 5000 watts. Working space inside is 4" in diameter and 36" deep. Outside diameter is 14¼".—*Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.*

Recording A-c. Bridge

An a-c. bridge for rapid recording of changes in cable, capacitors, and insulating materials is designed for use in connection with life tests, and during treating and production processes. While undergoing manufacturing processes, and especially during accelerated life tests, these materials undergo physical and chemical changes which may be detected by measurements of their dielectric power-factor and capacitance. Records of changes are usually obtained by plotting point-by-point measurements made on a manual bridge. New bridge is capable of operation 24 hours a day without attention, and can record changes within one second. In addition to a conventional Schering bridge, equipment includes a voltage amplifier, phase selectors, Thyratron circuits and motors, and recorders. Amplifier increases the feeble signal appearing at output of bridge when unbalance occurs, so that sufficient voltage is available to operate the phase-selector circuits. Phase selectors separate the voltage components of bridge unbalance produced by specimen changes. These components cause the proper Thyratron to supply power to motors which rebalance the bridge. Two recorders show the position of the balancing elements in the Schering bridge, recording capacitance and power-factor of the specimen. Chart speeds of 1" per minute and 1" per hour are provided. Switches for changing bridge range, giving a signal, or discontinuing the test may be located on the balancing elements to handle changes larger than anticipated. — *General Electric Co., Schenectady, N. Y.*

For Extremely Close Temperature Control

Visual-Stats



● Sensitivity of a hundredth of a degree is easily attainable. ● Top of mercury column visible at control point (where most important) because electrodes terminate at back of tube. No encircling metal bands! ● Available in angle form (illustrated) or conventional straight form. ● Send for brief, attractive bulletin.

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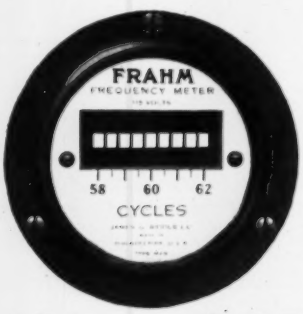

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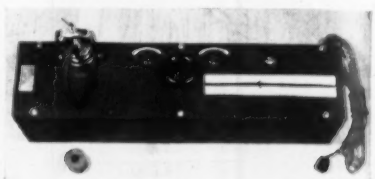
Permeameter

New Hayward Permeameter operates on a principle different from that of other equipments for core analysis determinations. Standard rubber bushings, containing core



sample, are clamped into permeameter core holders; a handwheel is turned in the direction indicated by pilot lights; this is the only manual operation. Permeability of the core is read directly in millidarcys. No calculations are required if a standard core size is employed. For odd-shaped samples one determines permeability by a single multiplication with the length-area ratio. New permeameter is said to be independent of variations which require careful consideration in the classical method of permeability determination. Sensitivity and accuracy are said to be comparable with meters now in use. Instrument is inherently free from effects of humidity and temperature variations. No liquids being employed, leveling is unessential. Air flow through the sample is said to remain in the laminar region without attention. The instrument is self-contained, requires no external air supply, weighs 50 lbs., operates from 110-volt a-c. or d-c. supply. — *Engineering Laboratories, Inc., 624 E. Fourth St., Tulsa, Oklahoma.*

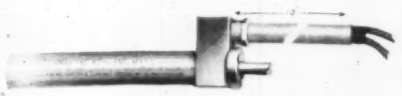
Thermocouple Protecting Tube

New type of thermocouple protecting tube, designated "Carbolast," has been developed particularly for foundries to protect the thermocouple wires against action of molten

copper alloys. Tube material is a metallized refractory said to possess light weight and high mechanical strength. It has a heat transfer approx. 20% greater than a metal tube of the same wall thickness. Slag and molten metals do not adhere to the tube. Cleaning after immersion is unnecessary. It is said that because the tube disintegrates by sublimation rather than chemical action there are no metals or temperatures to limit its use. It can be used in molten aluminum alloys and copper alloys without fear of contaminating either metal. In heat-treating work it increases pyrometer accuracy by minimizing lag. It will not bend under its own weight when projected into the furnace; is said to have long life in all atmospheres but is not recommended for applications under impact of abrasive particles. Maker furnishes "Carbolast" Protecting Tube as a complete fixture comprising 6", 8" or 12" protecting tubes, thermocouple wires and 10" extension to fit lance pyrometers used in foundry work. Tubes are also available in lengths up to 6 ft. and 1½" in diameter for general protecting tube applications. — *Electric Mfg. Co., Instrument Div., Harvey, Ill.*

...mersible Form of Thermal Switch

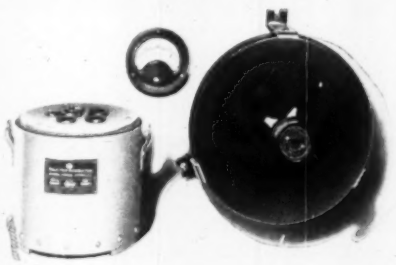
...mersion Thermoswitch" has been re-...ed by providing a hermetic seal for ...justing screw as well as water-tight ...t for the leads. This permits adjust-



...ing the device while it is totally submerged ...liquid, hot wax, etc. For detailed descrip-...n of "Thermoswitch" as a temperature ...ntroller see *Instruments*, July 1938, page ...The standard adjustable range is from −50° ...F. to 400°F. Contact rating of "series 700" ...0 amps. at 115 volts; of "series 800" 25 ...mps. at 115 volts; both a.c. Special models ...available for temperatures to 600°F. and for ...d.c. circuits.—*Fenwal Inc., Ashland, Mass.*

Carbon Residue Apparatus

New "TAG A.S.T.M. Ramsbottom Carbon Residue Apparatus" may be used for determining the amount of carbon residue of lubricating oils, fuel oils and other similar products such as light distillate, left on evaporating in oil under specified conditions. A similar type of apparatus has been widely used throughout the British empire but has only recently come into common use in this country. It is intended to replace the Conradson type of carbon residue apparatus



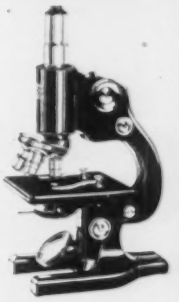
since it gives more accurate results which can be duplicated in different laboratories to greater precision. Bath is constructed of cast iron and is electrically heated, control being effected by a rheostat. The stainless steel coking bulbs into which the samples are placed are heated to 1020°F. This temperature may be measured either by an electrical pyrometer or a high-temperature glass thermometer made of American heat-resisting glass. Bath liquid is pure lead, experiments having shown that a molten bath of this type is satisfactory, takes up a relatively small space, may be heated rapidly and its temperature controlled conveniently.—*C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

Electron-tube Multi-purpose Electrical Instrument

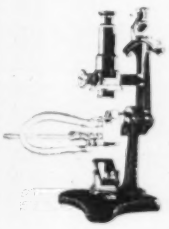
New "Model 661" electron-tube volt-ohmmeter serves also as microfaradmeter, is said to be the first of an entirely new group of test instruments to be offered by maker. It is said to be characterized by unusual flexibility, making it suitable for a wide range of applications in radio, electronic and electrical service fields as well as in the laboratory. Features which contribute to flexibility are: Input resistance, 16 megohms (low) to 160 megohms; a-c.-d-c. volt-age range, 0.1 to 6000 volts; resistance range, 0.1 ohm to 1000 megohms; capacity test range, 0.00005 to 600 microfarads. Instrument case is all-metal, with 4½" rectangular indicator mounted on panel. All necessary accessories are included.—*Radio Products Company, 88 Park Place, New York City.*

Spencer Instruments for Industrial Control

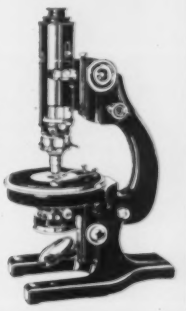
Spencer Stereoscopic Microscopes are used for the examination of details too small to be seen by the unaided eyes—to examine impurities or inclusions in raw materials, flaws or irregularities in materials being processed, surface characteristics of finished products. A vivid three dimensional image is obtained.



The Spencer No. 33 Microscope is adaptable to almost any type of microscopic examination and is designed for convenience in quickly changing magnifications or types of illumination, for photomicrography, for measuring, counting or examination of materials.



The Spencer Refractometer provides a quick and accurate method for determining the refractive indices of liquids and solids.

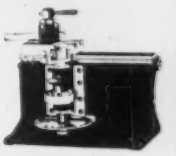


The Spencer No. 41 Polarizing Microscope is used for identification of crystalline materials by means of their optical constants.

Direct Result COLORIMETER is used wherever characteristic color is produced proportional in intensity to the concentration of a substance in solution.

The Spencer Microtomes are used for cutting cross-sections of material for microscopic examination of structure, results of processing, etc.

Write Dept. No. B32 for catalogs describing these instruments more completely.



Spencer Lens Company

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REFRACTOMETERS
COLORIMETERS
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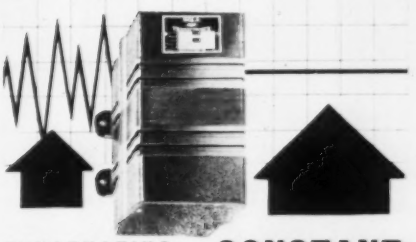

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WHEELCO SURFACE TEMPERATURE PYROMETER

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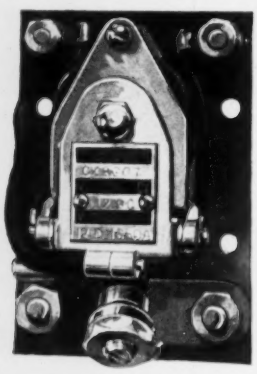
Concentration Controller

New "Solu-Bridge Controller" combines analytical function of maker's "Solu-Bridge" (*Instruments*, Oct. 1939, page 274) with a sensitive vacuum-tube relay commanding a

suitable alarm, or an electromagnetic control valve, or both. A continuous sample of the solution or condensate flows through a remotely-located cell whereby its electrical conductivity is continuously measured by a stable Wheatstone bridge utilizing a "magic eye" balance indicator (top of instrument panel). At bottom of panel is a small dial which is set for the approximate temperature of the solution or condensate. In center of panel is large main dial which operator sets for desired concentration. Instrument may be arranged to close or to open the relay contacts, as may be desired. Relay is positively actuated by vacuum-tube circuits, handles an external current up to 2 amperes at 110 volts.—*Industrial Instruments, Inc., 156 Culver Ave., Jersey City, N. J.*

Motor Reversing Relays

Two new light-weight, vibration-proof relays designed primarily for aviation service (control of air flaps, etc.) are offered for industrial requirements. Non-welding con-



tacts are said to make them suitable for use with lamps, motors or other devices where high inrush loads are likely to be encountered. "Type C3007" is s-p. s-t. with normally open contacts rated 50 amps at 12 or 24 volts d.c. It will stand an inrush of 100 amps. Contact pressure is 10 lbs. Coils are rated 8 watts continuous and are for operation only on d.c. Dimensions $2\frac{3}{4}$" × $1\frac{7}{8}$" × 2"; weight 8 oz. Two of these, mounted on a common base for motor reversing are $3\frac{3}{8}$" high × 4" wide × 3" deep, and weigh 15 oz. A larger relay, "Dunco CXA3008," is rated 100 amps at 12 volts d.c. or 80 amps at 24 volts d.c. and will stand an inrush of 300 amps. Coil is 10 watts continuous, contact pressure is 15 lbs. Size $3\frac{3}{4}$" × $2\frac{1}{2}$" × $2\frac{3}{8}$"; weight 21 oz. Modifications of either unit can be supplied to meet individual requirements. — *Struthers Dunn, Inc., 1335 Cherry St., Philadelphia, Pa.*

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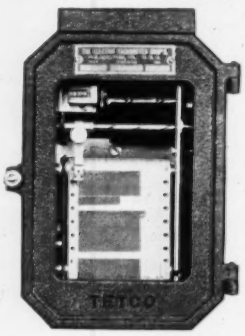

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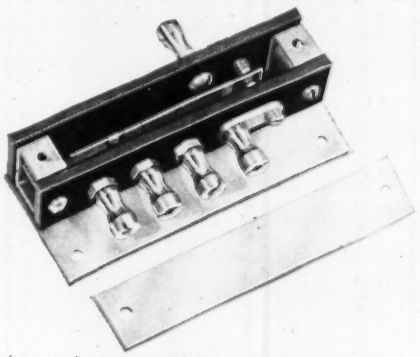
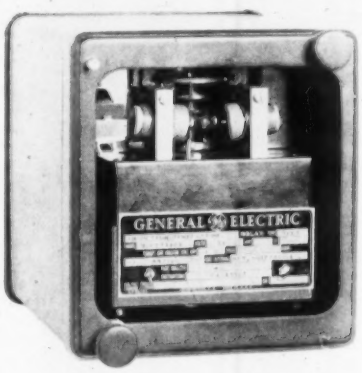


lays, where temperature changes are "fairly constant" and slight variations in timing are not detrimental. (Special compensating switches are provided where accurate delay is essential.) Switches are provided with four terminals, two for heater coil and two for main circuit; are adjustable within time limits of one second to five minutes. Available in immediately or not-immediately recycling types, normally-open or normally-closed models. Size with soldering lugs 3" × $\frac{7}{8}$" × $\frac{7}{8}$"; with binding posts 3" × $\frac{7}{8}$" × $1\frac{1}{4}$".—*Betts & Betts, 551 W. 52nd St., New York City.*

Temperature Relay

For protection of machines and transformers against overloading, improved temperature relay, designated "Type CFT," is of induction-cylinder design, and supersedes



"Type ICT" induction-disk relay. No change has been made in the circuit; and new relay still serves as the galvanometer in a Wheatstone bridge circuit comprising a resistance temperature-sensitive element in one arm and tapped bridge resistors in the other three arms. In this application, normal operating region of relay is, of necessity, close to pickup point. Consequently, high-torque characteristic of induction-cylinder feature provides more dependable and more consistent protection than was afforded by induction-disk design. Usual adjustment of this relay will be the same as that of previous type. It is adjusted to close its low-temperature contact at 80°C, and its high-temperature contact at 95°C, with a 30°C ambient. Balance point is midway between, as determined by the tap used on each of the three tapped bridge resistors. The other taps permit adjustments, so that the balance point can be made higher or lower, and still keep range between contact closings. With a given adjustment, relay is said to be little affected by ordinary variations in voltage supplied to bridge circuit. For example, the high-temperature contact will make within ±1% of the same temperature for a supply voltage of 80% to 110% of rated voltage.—*General Electric Co., Schenectady, N. Y.*

A New Method of Determining Voltage and Phase Relations in an A-c. Bridge Network

By J. R. BARNHART

The Hickok Electrical Instrument Co., Cleveland, Ohio

In describing bridge measurements the Wheatstone bridge has always been presented as the classic example. It deserves this distinction. Its simplicity appeals at once to our sense of reason.

In comparing an unknown magnitude with a known standard, the galvanometer will deflect in one direction if the unknown is higher than the standard. It will deflect in the opposite direction if the unknown is lower and will not deflect at all if the unknown is equal to the standard. We accept this unquestioningly as being as it should be. The d'Arsonval galvanometer used as the indicating means in the Wheatstone bridge circuit is another example of simplicity.

Altogether the Wheatstone bridge in principle, precision, simplicity and sturdiness, fills a need in electrical measurements. It will always be a staple instrument. However, the Wheatstone bridge is suitable only for direct current measurements. Also, upon close analysis, we find that the internal resistance of the galvanometer seriously limits its useful range.

Bridge designers are forced to resort to what is called optimum conditions. The galvanometer is designed for maximum response to minimum change in bridge balance.

Measurement of high impedances, say of the order of 100 megohms or higher, is difficult with the conventional Wheatstone bridge on account of the relatively low impedance of the galvanometer. It is necessary to use an extremely delicate reflecting galvanometer and high battery voltage so that the bridge equipment is more or less cumbersome.

Capacity, inductance and certain kindred measurables such as power factor cannot be measured with the Wheatstone bridge. Excellent instruments have been built for this purpose but they have lacked the forthrightness of the Wheatstone bridge. An alternating-current bridge that would operate in the same manner as the direct-current bridge was a thing to be desired. It was this thought that led to the development of the bridge herein described.

A rugged d'Arsonval galvanometer is connected to the alternating-current bridge network by an electronic circuit

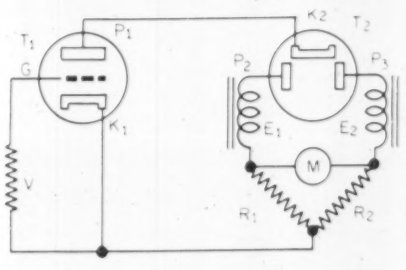


Fig. 1

so that the operation is the same as with the conventional Wheatstone bridge, but with galvanometer impedance increased manyfold.

The conventional bridge is balanced when the balance indicator shows that no voltage exists between two given points in the bridge network; the galvanometer or other indicating means recognizes only existence or non-existence of voltage.

In the bridge described herein the galvanometer recognizes not only presence or absence of voltage, but also phase displacement. This permits electrical triangulation—which is not possible with the conventional bridge.

The essential feature of this new bridge is the cosine galvanometer shown schematically in Fig. 1.

T_1 is a triode tube consisting of plate P_1, grid G and cathode K_1. T_2 is a rectifier tube consisting of cathode K_2, plate P_2 and Plate P_3. E_1 and E_2 are equal windings on a transformer. Connections are made so that when P_2 is positive P_3 is negative. R_1, R_2 are equal resistances. M is a d'Arsonval galvanometer. The operation is as follows: When P_2 is positive, current flows P_2, K_2, P_1, K_1, R_1, E_1 to P_2. A portion of the current is shunted through R_2 and M, causing the galvanometer to tend to deflect, say, to the left.

When P_3 is positive, current flows P_3, K_2, P_1, K_1, R_2, E_2, to P_3. A portion of the current is shunted through R_1 and M, causing the galvanometer to tend to deflect to the right.

Because of the inertia of the moving element of the galvanometer, the pointer cannot follow the current alternations. Consequently, to the eye, the pointer is motionless.

If now, potential is applied to the grid G, across V, in phase with E_1, the current tending to move the pointer to the left will be increased and current tending to move the pointer to the right will be decreased. Consequently, the pointer moves to the left. Conversely, if the potential on G is in phase with E_2, the pointer will move to the right.

If the potential on G lags E_1 and leads E_2 by 90 electrical degrees, or vice versa, the pointer will not deflect. For any intermediate phase angle between G and E_1 (E_2) the deflection of the galvanometer is proportional to the cosine of the phase angle. Whether phase is leading or lagging can be determined by the direction in which the galvanometer deflects. The circuit elements shown in Fig. 1 function as a phase discriminator.

It is thus seen that zero deflection occurs (1) when no voltage exists across V and (2) when the cosine of the phase angle between G and E_1 (E_2) is zero.

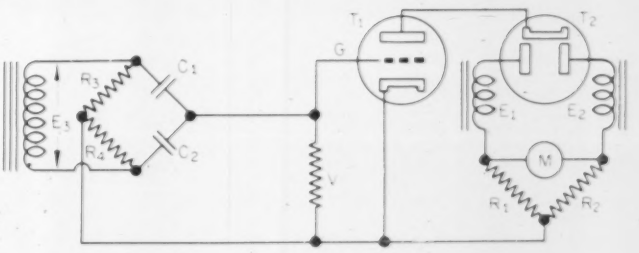


Fig. 2

Fig. 2 illustrates the operation of a simple bridge. E_1, E_2 and E_3 are all windings on the same transformer. Therefore they all have "in phase" relation. R_3 and R_4 are adjusted until zero deflection occurs.

Then $$R_3/R_4 = C_2/C_1$$

In this case zero deflection occurs because there is no voltage across V.

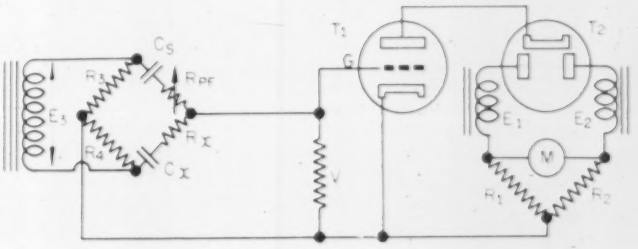


Fig. 3

In Fig. 3 is illustrated the method of determining power factor. The emf's E_1 and E_2 are adjustable in phase relation to E_3. C_s represents a standard capacitor having zero power factor. C_x represents the unknown capacitor with its equivalent series resistance, R_x. R_3 and R_4 are adjusted for

zero deflection of M. In this case zero deflection occurs because the cosine of angle between G and E_1 (E_2) is zero.

The vectors of voltage relations across the bridge are shown in Fig. 4.

The straight line W, O_2, Z represents the voltage E_3 across R_3, R_4 in series. W, O_2 is the voltage across R_3 and O_2, Z is the voltage across R_4. O_2,m represents the voltage across the grid leak V. But because it is 90 degrees out of phase with E_1, E_2 and E_3 the galvanometer shows zero deflection.

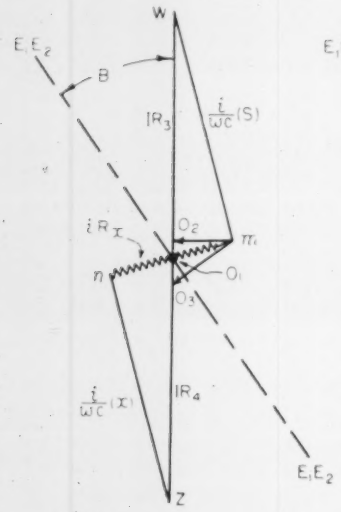


Fig. 4

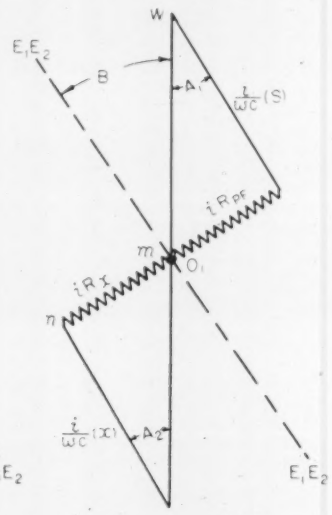


Fig. 5

The phase of E_1, E_2 is now shifted until it is out of phase with E_3 by the angle B. In this case zero deflection is obtained when O_3,m is 90° out of phase with E_1,E_2. The resistance R_{pf}, in series with the standard capacitor, is then adjusted until zero deflection occurs when E_1, E_2 is in either phase. The voltage vectors are shown in Fig. 5. The point m coincides with O_1 and no voltage exists across V. The angle A_1 equals A_2.

$$\text{Power Factor} = iR_{pf}/WO_1$$

and can be calibrated on a dial associated with R_{pf} for a given capacitor, C_x.

Capacity can be determined to a high degree of accuracy without a standard capacitor. The connections are shown in Fig. 6.

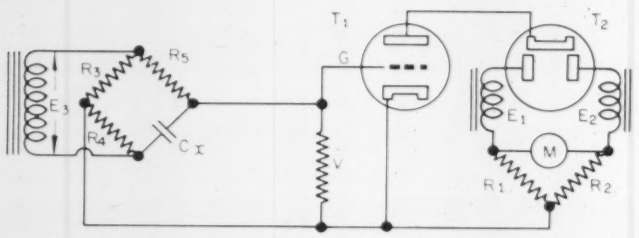


Fig. 6

R_5 is an adjustable resistance box, or it may be a fixed resistor the value of which is known. R_3 and R_4 are adjusted for zero deflection of M. The voltage vectors are shown in Fig. 7.

W,O,Z represents the voltage across R_3, R_4 in series. W,m voltage across R_5 and m,Z voltage across capacitor C_x. O,m is normal to W,Z. Then from the principles of geometry,

$$\sqrt{\frac{R_3}{R_4}} = \frac{R_5}{1/\omega C}$$

from which $$C = \sqrt{\frac{R_3}{R_4}} \times \frac{1}{\omega R_5}$$

In the special case where R_3 equals R_4 and balance is obtained by adjusting R_5, $C = 1/\omega R_5$

Power factor of capacitor can be found as in Fig. 8. There, xL becomes xC and equivalent series resistance Q is found exactly as for inductor.

$$\text{Power Factor} = \frac{(Z_2)^2 - (Z_1)^2 - r^2}{2rZ_1}$$

If capacity can be measured in terms of resistance and frequency, it follows that frequency can be measured in terms of resistance and capacity. The connections are shown in Fig. 6. Instead of the capacitor C_x, a capacitor of known value is used.

A convenient way is to make R_3 equal R_4 and adjust R_5 for balance. Then the following relation holds:

$$F = \frac{1}{2\pi R_5 C}$$

The impedance of an inductor can be found in terms of resistance and frequency the same as capacity. Because an iron-core inductor always has an equivalent series resistance the true value of inductance, also equivalent resistance, can

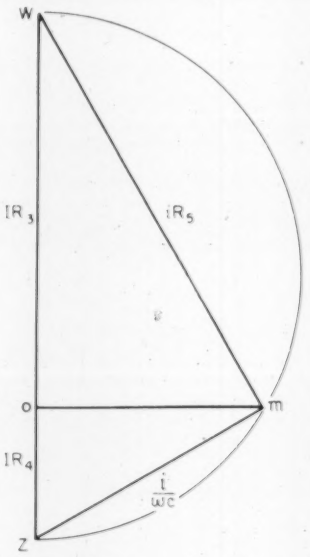


Fig. 7

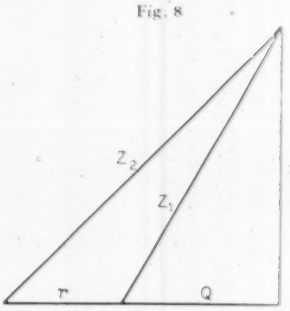


Fig. 8

be found as in Fig. 8. Make R_3 equal R_4 then the square root of the ratio is 1. Adjust R_5 for balance. R_5 equals impedance, Z_1, of inductor. Insert a resistance, r, say 1000 ohms, in series with the inductor. Adjust R_5 for new balance. The new value of R_5 equals Z_2.

Q represents the equivalent series resistance.

$$\text{Then} \qquad Q = \frac{(Z_2)^2 - (Z_1)^2 - r^2}{2r}$$

from which xL can be found.

The cosine galvanometer can be used as a balance indicator in any a-c. bridge circuit. It is merely necessary to have voltages E_1, E_2, in Fig. 1, in phase with the voltage applied to the bridge network.

Synchronism between two alternating-current circuits can be determined by energizing E_1, E_2 from one source and feeding a small voltage from the other source across V, Fig. 1. As the two circuits approach synchronism the galvanometer pointer will travel slowly from side to side, finally coming to rest when exact synchronism is reached.

Zero phase angle is secured when the pointer comes to rest at maximum displacement to one side of zero. 180-degree phase angle exists when maximum displacement is on opposite side of zero.

When standard connections have been established, zero-phase angle is always indicated by maximum pointer deflection to a given side of galvanometer scale.

Frequencies other than commercial power line frequencies can be used by having the voltages E_1, E_2, E_3, Fig. 2 generated by a vacuum tube or Vreeland oscillator. Cathodes of T_1 and T_2 can be heated from commercial power line.

Extremely small inductances (microhenries) and capacitances (micromicrofarads) can be measured.

Pressure-transmission Lag in Remote-indicating Pressure-spring Thermometers

By H. A. ROLNICK
Director, Trent Engineering Laboratories, Philadelphia

THIS article discusses those thermometers comprising (1) a metal bulb containing a liquid, vapor, or gas for the thermometric substance, (2) a tube connecting the interior of the bulb to (3) a pressure-responsive element—generally a Bourdon tube in the form of a flat spiral or helix. In the design and use of such remote-indicating thermometers an important factor is the time elapsed between a temperature change in the fluid being measured and the "final" indication at the instrument. This lag (of considerable importance in control applications) is the result of two different effects. Part of it is thermometric lag, chiefly due to the rate of heat transfer from the fluid being measured to the thermometric substance in the bulb. The other part is the lag in transmitting the pressure change in the bulb through the capillary connecting tubing to the pressure-spring. In this article will be discussed only the latter effect—the lag in transmitting the pressure change.

This probably is the first quantitative treatment of the pressure-transmission lag—a characteristic whose effects are sometimes greater than most thermometer users would expect. Dr. Rolnick (formerly with Brown Instrument Co.) discussed air-inclusion errors in our last issue. In an early issue he will report the results of his original research on still another characteristic.

Throughout the discussion, it is assumed that the temperature changes of the bulb are instantaneous. Actual time lags due to delay in transmitting pressure changes will be somewhat longer than those given in this article. A more detailed analysis (which it is not necessary to reproduce here) indicates that the slowing-up effect of the pressure lag is most pronounced at the beginning. Roughly, the total lag constant due to pressure lags and heat transfer lags can be obtained by adding the two lag constants.

Remote-indicating pressure-spring thermometers use for a thermometric substance either a liquid, or a volatile vapor, or a gas. The actuating pressures in these various classes are produced in a different manner for each one. So each class will be treated separately. In each case will be discussed the pressure change due a temperature change at the bulb, and formulas will be given for the rate of pressure change at the pressure-sensitive element.

I—Liquid-filled Thermometers

In this class, the thermometric substance is a liquid. The most commonly used ones are mercury, alcohol, xylene, and toluene. The bulb, connecting tubing and pressure-spring are completely* filled with the liquid.

A—Rising Temperatures

On a sudden rise in temperature at the bulb, theoretically the increase in pressure of an incompressible liquid may be enormous enough to cause a permanent increase in dimensions of the bulb. In the writer's experience, however, this has rarely been observed, so that apparently, the rate of heat transfer in the commonly-used combinations of thermometric liquid and bulb material is not sufficient to develop the enormous pressures theoretically possible before the flow into the connecting tubing reduces the pressure. A rise in temperature at the bulb of a liquid-filled thermometer, before any liquid flows out from the bulb, causes a volumetric increase which elastically stretches the bulb walls and causes the pressure increase which is calculated below.

The thermal expansion of the liquid equals the volumetric expansion of the bulb. In the form of an equation, this relation is expressed as follows for a long cylindrical bulb.

$$aV_o(T' - T_o) = KV_o(P' - P_o) = \frac{1.25D(P' - P_o)V_o}{bY} \quad \ldots \quad (1)$$

a = relative thermal expansion of liquid and bulb
V_o = original bulb volume
$T' - T_o$ = temperature change
K = compressibility of liquid
$P' - P_o$ = pressure increase due to temperature increase
D = diameter of bulb
b = thickness of bulb wall
Y = Young's modulus for bulb material

Rewriting the above

$$P' - P_o = \frac{a(T' - T_o)}{1.25D/bY + K} \quad \ldots \quad (2)$$

Under this pressure increase, the liquid will flow through the connecting tubing to the pressure-sensitive element. The pressure in the pressure-sensitive element will rise at a rate proportional to the increase in the amount of liquid forced into it. The rate of flow of liquid into the pressure element (and hence the rate of indication of the temperature) will obey the following law of flow:

$$\frac{dV}{dt} = \frac{\pi r^4}{8ln}(P' - P) \quad \ldots \quad (3)$$

dV/dt = rate of flow of fluid—volumetric
r = internal radius of capillary connecting tube
l = length of connecting tubing
n = viscosity of fluid
P' = bulb pressure after temperature change
P = helix pressure at time t.

From equations 1 and 3 we get a relation involving rate of pressure increase at the pressure-sensitive element. The differential equation so obtained cannot be integrated, so that a step-by-step solution must be used to get the answer. An example has been calculated to give an approximate idea of the magnitudes involved. The time lag is approximately proportional to the length of capillary tubing, decreases rapidly with increase in capillary tubing diameter, and increases with increase in bulb wall thickness. The latter effect is due to the higher pressures developed in a thicker bulb as can be seen from equation 2.

Example—A mercury-in-steel bulb has a bulb diameter of $\frac{1}{2}$", wall thickness 1/16", internal volume 10cc., 100 feet of connecting tube with a diameter of 0.008", and a pressure-sensitive element requiring a pressure increase of 130 lbs. in.$^{-2}$ for each 0.01cc. change in its volume. For this system 1.2 seconds is required to indicate $\frac{2}{3}$ of a sudden temperature increase of 20% of the full-scale span of the system. About 2.7 seconds would be required to indicate 9/10 of the same temperature increase.

B—Falling Temperatures

On a sudden drop in bulb temperature, the pressure in the bulb falls to zero and the pressure-sensitive element forces some liquid into the bulb. The same equations for flow and pressure apply in this case as for a rise in bulb temperature. A calculation of the lag in the same thermometer as used in the example above gave the following results: 2.0 seconds required to indicate $\frac{2}{3}$ of a sudden temperature change and 5.7 seconds for 90% when the final temperature change is 20% of the full-scale span. The pressure in the bulb was zero for 1.7 seconds.

*Not quite completely in practice. See: H. A. Rolnick, Air-inclusion Errors in Liquid-filled Thermometer Systems, *Instruments*, 14, March 1941, pages 71-72.—Editor

II—Vapor-pressure Thermometers

In this class, the thermometric system is partly filled with a volatile liquid. The pressure at the bulb end depends on the temperature-pressure characteristic of the volatile material used in it. Hence, for any temperature at the bulb, the pressure resulting is definite and liquid is forced into or out of the pressure-sensitive element until the pressure is equalized throughout the system.

A—Rising Temperatures

After a sudden temperature increase at the bulb, the flow of liquid into the pressure sensitive element is given by equation 3. The pressure change due to the increase of liquid in the pressure-sensitive element is given by the following:

$$V = kP + V_o \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

V = Internal volume of pressure-sensitive element
V_o = Internal volume at zero pressure
P = pressure in pressure-sensitive element.
k = constant giving ratio of volumetric change to pressure change of pressure sensitive element.

From 3 and 4 is obtained

$$t = \frac{8lnk}{\pi r^4} \log \left(\frac{P' - P_o}{P' - P} \right) \quad \ldots\ldots\ldots\ldots (5)$$

where P' = pressure in the bulb after the temperature change.
P_o = pressure in the bulb before the temperature change
P = pressure in the pressure-sensitive element at time, t.

The other symbols have been defined above.

The logarithm in equation 5 is a natural logarithm (to the base e) and the value of this term when the $P'—P$ = 37% of $P'—P_o$ is 1. When $P'—P$ is 10% of $P'—P_o$ the value of the logarithm is 2.3; when $P'—P$ is 2% of $P'—P_o$ its value is 3.9; the value when $P'—P_o$ is 1% of $P'—P$ is 4.6.

The equation indicates that the lag depends on the length of the capillary connecting tubing, its diameter, the viscosity of the liquid and the ratio of volumetric change to pressure change of the pressure-sensitive element. This latter characteristic is one which has often been overlooked so that the lag for some makes of vapor-pressure thermometers has been far greater than was suspected.

An example will be calculated below which will give some idea of the magnitudes involved and will show how a poorly selected pressure-sensitive element can give rise to large lags.

A system with 100 feet of 0.018" I.D. connecting tubing, containing ethyl alcohol, using a pressure spring with an expansion rate of 0.013cc. per lb./in.^{2}, is calibrated for a temperature span of 50 to 250 F. The bulb is moved from tap water to boiling water. The time for a temperature of 197 F. (98% of the temperature change) to be indicated will be 84 seconds. A properly designed pressure-sensitive element can reduce the lag to one-tenth of this value.

B—Falling Temperatures

The same equation (5) is equally applicable in this case. Owing to the decreasing rate of pressure change with decreasing temperatures, the ratios of pressure changes for the same temperature intervals will be different and time lags will differ at different points on the temperature scale. For smaller temperature changes the time lag for an increasing bulb temperature and the time lag for a decreasing bulb temperature approach one another.

III—Gas-filled Thermometer

In this class, the thermometric system is filled with a gas far enough from its critical temperatures and pressures to follow the gas laws. Usually, an inert gas like nitrogen is used. In designing a thermometric system of this type, the internal volume of the bulb is made large in comparison to the internal volume of the connecting tubing and pressure-sensitive element, to reduce the effect of ambient temperature changes.

A—Rising Temperatures

A sudden temperature increase at the bulb results in a pressure increase following Charles' law. Gas flows through the connecting tubing. The law of gas flow through the tubing is that given by equation 3. Since there is practically no change in volume of the thermometric system, the gas density has to be considered. At the pressure-sensitive element, the following relation holds:

$$P = mVd \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

where P = pressure in sensitive element
V = volume of sensitive element
d = gas density in sensitive element
m = ratio of pressure change in pressure element to mass of gas in it.

Combining equations 3 and 6 finally leads to the following expression for time lag:

$$t = \frac{V}{P'} \times \frac{8lu}{\pi r^4} \times \log \left(\frac{P' - P_o}{P' - P} \right) \quad \ldots\ldots\ldots\ldots (7)$$

where t = time lag
V = volume in pressure sensitive element
P' = final pressure in sensitive element and in bulb
l = length of capillary connecting tubing
u = gas viscosity
r = radius of connecting tubing
P_o = initial pressure in bulb before the temperature change
P = pressure in pressure sensitive element at time t.

The logarithm in equation 5 is a natural logarithm (to the base e) and the value of this term when the $P'—P$ = 37% of $P'—P_o$ is 1. When $P'—P$ is 10% of $P'—P_o$ the value of the logarithm is 2.3; when $P'—P$ is 2% of $P'—P_o$ its value is 3.9; the value when $P'—P_o$ is 1% of $P'—P$ is 4.6. The lag of pressure change is directly proportional to the volume of the pressure-sensitive element, the length of capillary tubing and the gas viscosity.

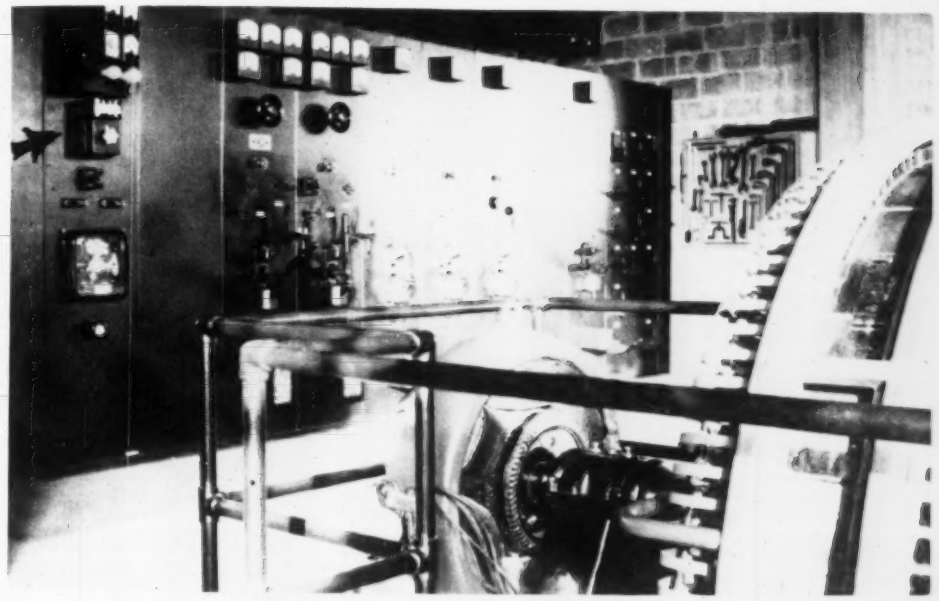
For a thermometer filled with nitrogen and having a scale span of 0 to 250 F., 100 feet of 0.018" I.D. connecting tubing, the time taken to indicate a temperature of 140 F. when the bulb is placed from a liquid at 100 F. to one at 150 F. is 0.26 seconds; the time to indicate a temperature of 149 F. (98% of the final change) is 0.5 seconds. If tubing 0.008" I.D. instead of tubing 0.018" I.D. were used in this system the lags of pressure change would be twenty-six times as great, and thirteen seconds would elapse before 98% of a sudden temperature increase at the bulb would be indicated at the dial of the instrument.

B—Falling Temperatures

The speed of response for decreasing temperatures is about the same since the pressure-sensitive element loses pressure at the same rate for a given pressure difference between bulb and element whether the pressures are increasing or decreasing.

MRS. E. F. LOVEJOY

On February 27th death came to the person who read Instruments Publishing Company publications more assiduously than anyone else in the world . . . and whose place can never be filled. Mrs. Ellen Fancher Lovejoy was head proofreader for the Herbick & Held Printing Co. (our printers) but above and beyond her routine work she displayed a kindly and wise understanding of a multitude of details, so that we all thought of her as a valued friend. Mrs. Lovejoy's experience in printing covered four decades; at eighteen she began setting type for the Warren, Ohio, *Chronicle*, later becoming its society editor. She married a country editor and could tell many stories of collecting overdue accounts in farm produce. Mrs. Lovejoy had been with Herbick & Held since 1926.



Saving Fuel with a Pyrometer

Awarded an Honorable Mention in the 1940 ("Speeding Up National Defense") Instrumentation Contest

By JAMES F. MAHER

Assistant Engineer, U. S. Indian Service, Dep't of the Interior, Shiprock Power Plant, Shiprock, N. M.

IN the field of internal-combustion prime movers using as fuel liquefied petroleum gas (sometimes called bottled gas, butane-propane gas, and by company trade names) it is essential for efficient and economical operation—and it is customary—to install pyrometers for indicating exhaust-gas temperatures. Fuel saving is an indirect result—seldom the primary purpose.

An "Alnor" multi-point pyrometer was installed with regular equipment when the plant was constructed, for usual exhaust gas temperature indications. After the plant was in operation, however, it came to our attention that the pyrometer served as an efficient fuel-saving indicator.

The liquefied petroleum gas being used in this particular power plant is of 2800 Btu./ft.^{3} and 1.6 sp.gr. and occasionally runs to 3000 Btu. It is supplied through eight miles of 2" copper pipe under pressure, direct from the oil field stabilization plant, with about 300 ft. drop in the line. Regulators maintain constant pressure and prevent excessive pressures (through pressure is necessary to maintain the fuel in the liquid state). From storage the fuel is vaporized and reduced in pressure and is supplied to the engine mixers in undiluted vapor form, where it is mixed with air and enters the engine manifolds.

It is found that weather, seasonal changes and stabilization plant winter and summer grade fuel changes, have a great effect upon engine operation and that this is apparent in pyrometer readings. As the density of the liquid varies and resulting changes occur in fuel consumption and exhaust temperatures, the pyrometer becomes an invaluable guide for correcting the conditions.

During the winter months the liquid fuel is heavier. However, at the same time the atmosphere is colder and more dense, and it is necessary to make adjustments to the mixers, or carbureters, to compensate for these changes in keeping fuel consumption at a minimum, and to maintain low exhaust gas temperatures. The amount of air entering the mixture under these fuel and weather conditions must be greatly reduced.

In early summer it is found necessary to increase the amount of air in the fuel mixture to keep engine speed, fuel consumption and pyrometer temperatures normal.

In winter, storage pressures are low and liquid level high, while in summer high pressures are necessary to keep the liquid storage level up to normal as it comes from the stabilization plant, showing the variation in density of the liquid.

With an extremely high Btu. gas such as this being used undiluted, slight adjustments of the valves in the mixers create a great difference in engine speed, pyrometer temperatures or fuel consumption, especially so when adjustments are made to the fuel valve. The pyrometer is essential to make these adjustments correctly, not only to maintain needed low fuel consumption and exhaust gas temperatures, but also for proper engine speed and governor control for load changes.

Most adjustments are made to the air valve only on the mixers, as this is more easily done, in that it is the air that must be increased or decreased in greater volume to give proper combustion with light or heavy gas.

More than 100 ft.^{3} hr. can be saved in fuel consumption if pyrometer readings are watched and adjustments made to the mixers at proper times.

It is found that fuel consumption will come down with pyrometer temperatures as more air is given to the fuel mixture, but though the fuel consumption remains low, after a certain point if an excess of air is given to the mixture, pyrometer temperatures will start rising. The reverse is true also: if an excess of fuel is given to the gas-air mixture the temperature will also rise with the excess.

No particular amount of adjustment can be specified to be made at the mixers, because atmospheric conditions, density of the liquid fuel, and load conditions, all must be taken into consideration at the time adjustments are made. Familiarity with the gas in use, as well as practice and close attention on the part of the operator, bring about a knowledge of the necessary changes to be made under the existing conditions. It is well that adjustments be made and taken care of by one particular operator as he becomes familiar with his equipment and gets to know the mixer settings and when changes have to be made. With several operators making changes to delicate and sensitive equipment, there would be confusion.

Constant and close attention is given to pyrometer readings in this particular power plant, and adjustments are frequently made to the mixers. Thus economical operation is obtained and the pyrometer "pays dividends" every month.

Proper Connections Increase Value of Gages

Awarded an Honorable Mention in the 1940 ("Speeding Up National Defense") Instrumentation Contest

By HENRY I. MORTON

Instrument Engineer, Star Brass Mfg. Co., Boston, Mass.

METHODS of connecting up pressure gages may be considered unimportant but National Defense needs every improvement that will increase the value of gages to industry, broaden the scope of their uses, and improve their response and accuracy. Through competition the manufacturer is constantly improving his product and the day of 0.25% accuracy is not far off. Mechanical precision and easy-reading dials can hardly compensate for poor installations. Therefore, I feel that to acquaint industry with other possibilities is to help production.

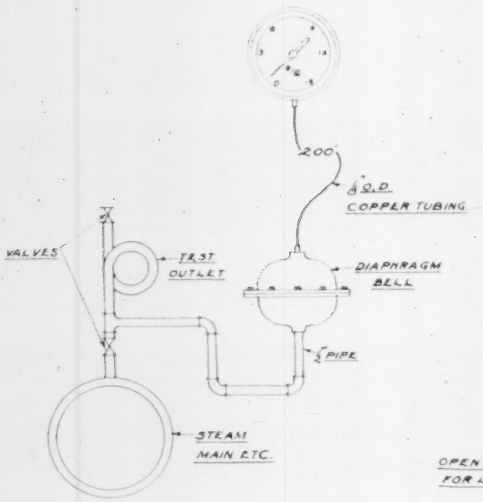


FIG. 1

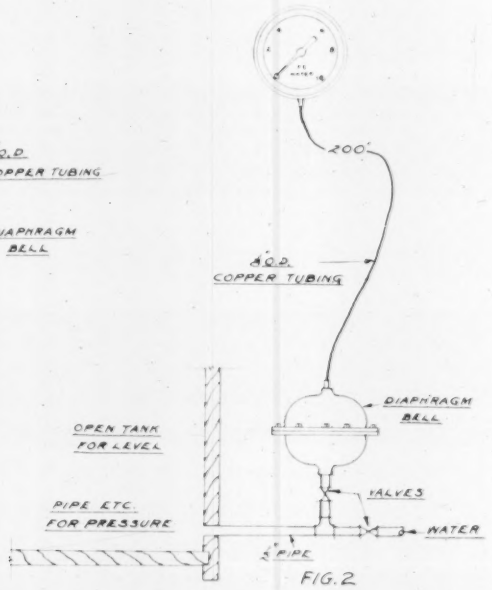


FIG. 2

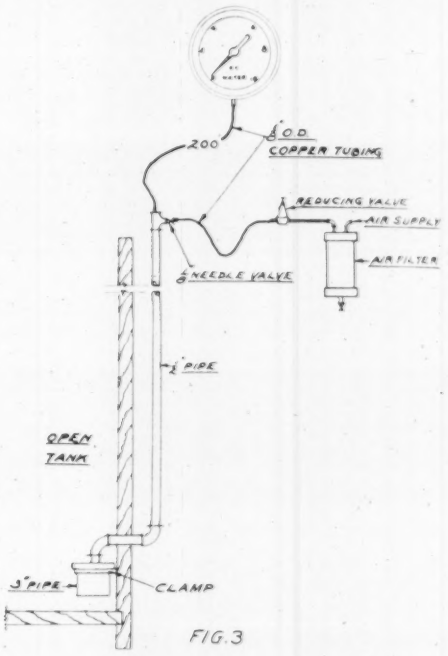


FIG. 3

In most industries pressure is a vital factor at one or more points in the process; and ability to control and regulate pressure directly influences uniformity and quality. The Bourdon-tube indicating gage and the helical-tube recording gage give accurate measures of pressure but due to location are of little value to an operator: the operator trusts to luck rather than make a tour of inspection to check pressures; if the gages are piped to a central location they become sluggish and inaccurate. In many cases the inexpensive Bourdon gage properly installed and frequently read by an alert operator would be the equivalent of an expensive automatic controller. By proper installation I do not refer to location on a water or air line but to cases where the pressure of condensate steam, of suspensions, of viscous liquids or of corrosive chemicals is vital to operation and location presents a problem. The three sketches in this article are examples of the solutions of location problems. Without response and accuracy the gage is a handicap and is soon ignored, but when care and thought are given to the installation, it is changed into a valuable instrument.

Fig. 1 is an example where the pressure on a steam line varied from 3 to 12 lbs./in.^{2} and the line was at some distance behind the machine. The original installation was the usual ¼" brass pipe to a gage on the front of the machine for the operator to control his process. The gage was set to correct for waterleg but due to the circuitous route necessary, the water in the ¼" pipe varied and since this waterleg was over 100% of the pressure most of the time control was poor. The problem was solved by the use of a temperature controller compensated for pressure, but drift required frequent resetting. When the gage and the pressure compensator were connected to the steam line as shown in Fig. 1, complaints stopped and except for periodical checking with a test gage, no servicing was necessary for the first year.

Fig. 1 is the simplest adaption of the diaphragm bell using a thin rubber or Neoprene diaphragm. The bell can be in a tank or pipe but it is usually more satisfactory and less expensive to attach the bell outside. The gage is connected to the bell by a length (up to 200 ft.) of ⅛" O.D. copper tubing and standard connectors. If care is used in making the connections tight, the system will stay pressured for several years. In one case, the system failed after four years of continuous service because of the corrosive action of chlorine on the tubing, but this did not affect the tight joint made by the connectors. Response with long lengths of tubing when used in a tank with 4 ft. of liquid is rapid enough for a 10 ft. gage to pulsate when the agitator starts and causes the liquid to surge.

Fig. 2 is the same arrangement as Fig. 1 except that it has a high-pressure water line connection at the diaphragm bell. The only requirement is that the pressure of the water stay above the pressure to be measured. This water line can be used in two different ways: one for periodic flushing, the other for continuous bleeding into the bell connection. Where a slight addition of water is of no importance this installation has been successful for pressures in pipes or levels in tanks of substances like pulp or paper stock, clay, lime, or starch. Also the bleeding of water through the bell connection affords protection against corrosive chemicals like the addition of chlorine to pulp. However, when the addition of water is not desirable, the connection can be flushed out periodically between batches.

Fig. 3 is the bubble pipe type of installation which is an alternate for Fig. 2, using air instead of water and omitting the diaphragm bell. It is especially useful for obtaining pressures of corrosive gases without endangering the gage. In the case of level in a closed tank of sulphurous acid, one bubble pipe at the top and one bubble pipe at

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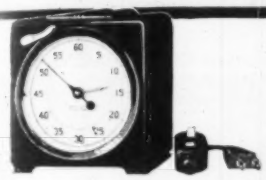

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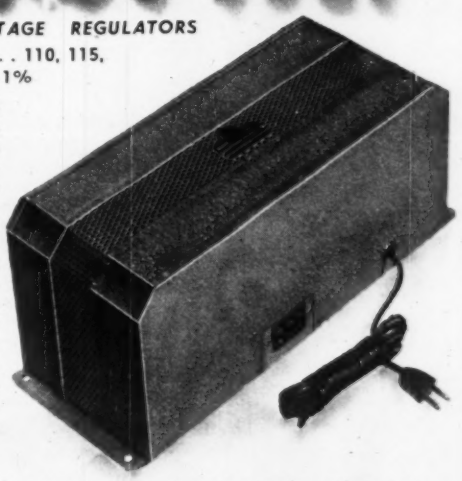

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the bottom will give the correct level on a differential gage as long as the over pressure is not high.

The details of Fig. 3 are the bubble pipe, the air line and the gage. The design of the bubble pipe varies with the application, as a gas line would take a standard $\frac{1}{2}$" pipe tee, the head on a weir or flume would take a 1" pipe of suitable material so it would not corrode and the level in a tank of a suspension or sticky liquid would use about 6" of 3" pipe reduced to $\frac{1}{2}$" and run above the tank. The air should be connected directly to bubble pipe and throttled by a needle valve. If there is the slightest possibility of plugging due to temporary air failure, the gage can be protected from the full compressor pressure when the air comes back on by adding a reducing valve and setting it for the maximum pressure of the gage. Bubble pipe installations appearing in several catalogs show the air connection at the gage but this is more expensive and inaccurate, as I found from experience. In the case of a thin suspension, I was able to check the head on a 6" V-notch to 0.01 foot every time and that was less than the expected accuracy of the recording instrument being used. The gage and connecting tube would be the same as used in Fig. 1 or 2.

Speed Measurement on Synchronous Motors

Awarded an Honorable Mention in the 1940 ("Speeding Up National Defense") Instrumentation Contest

By EUGENE HERZOG

Matériel Division, Air Corps, Wright Field, Dayton, Ohio

NEW types of aircraft propellers are tested for strength and efficiency on stands driven by electric motors. Because of various electrical and mechanical considerations, it has been found preferable to use synchronous motors in these installations. The noise and vibration are extreme at the motor and the danger due to possible breakage of the test propeller considerable. The test personnel is therefore located some distance away and protected at least from the danger of flying fragments. The problem under these circumstances was to devise a method of speed measurement which was sufficiently accurate (within one-fourth percent of the correct amount) and yet did not involve locating any of the personnel in the danger zone.

Indicating tachometers were not accurate enough; hand tachometers could not be used; tachometers that required mechanical connections for the integration of revolutions needed excessive lengths of flexible drives to the observation room.

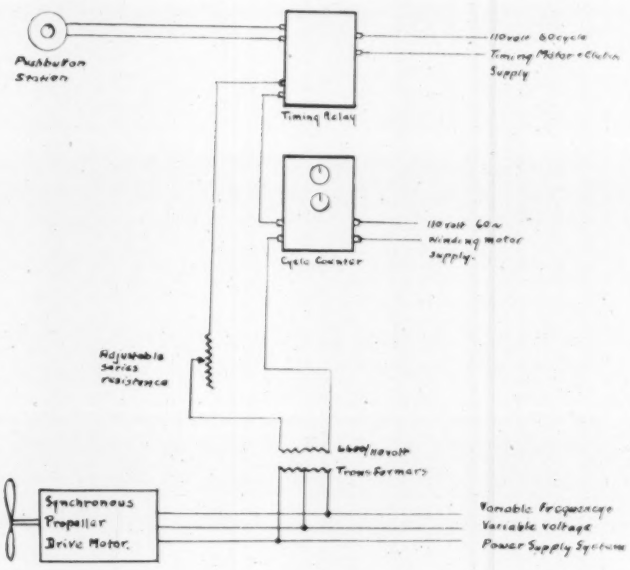
For some time the ordinary vibrating-reed type of frequency meter was used for the rough setting of the speed. This indicator was connected on the variable-frequency supply system to indicate the speed of the synchronous motor. However, its accuracy was not sufficient for the final determination of the speed.

The analogy of counting cycles instead of revolutions (permissible on a synchronous motor) was then carried one step further to determine more accurately the frequency and in consequence the speed. Equipment was installed to count the number of cycles in a fixed time. Cycle counters of sufficient accuracy were available, although used in the past only to measure the length of time elapsed on a fixed frequency system, for example, in relay and circuit breaker timing. The provision of the fixed time interval for 20 to 60 seconds with sufficient accuracy was more difficult because an instrument of unusually rugged construction had to be used under the particular circumstances. Finally such a timing relay was secured.

As installed, the complete speed counting device consists of the following two major parts: A cycle counter manufactured by the Westinghouse Electric & Mfg. Co. which was chosen among other things because the scale is calibrated in cycles and therefore reads directly in revolutions. The timing relay is the Microflex timer of the Eagle Signal Corp. of Moline, Illinois. This timing relay is adjustable and when set for a certain timing will repeat a one-minute interval within two cycles on a 60-cycle system. This is an accuracy of about one-twentieth percent. Although periodic checks so far have shown no decrease in accuracy, the device could deteriorate somewhat without exceeding the tolerance.

The various synchronous motors for the different speed ranges are built with different numbers of poles. In order that the reading of the cycle counter shall be directly in revolutions, the time interval held by the timing relays is set to correspond to the particular motor. On the two-pole motor the interval is set to one minute; on the four-pole motor one-half minute; on the ten-pole motor one-fifth minute. This is easily understood from the consideration that in the case of the four-pole motor, for instance, the motor makes one revolution for four reversals of the voltage or two cycles. If we then count one-half of the cycles, we shall have the true number of revolutions.

The timing relay is push-button operated. The timing motor runs continuously during test and pushing the control button closes the contact for the fixed interval, after



which the timer returns to the starting position. A speed count involves the following procedure: The cycle counter is set to zero, the push button is depressed and at the end of the time interval the speed is read. During the count the operator is free to read other instruments and the speed count does not require appreciably more attention than reading an indicating instrument.

Obviously the above method can only be used where the speed and the frequency are strictly proportional, although for high-accuracy measurement, a generator could be provided on the motor shaft if such condition is desired. The speed obtained is an average for the time interval. This may be a disadvantage where instantaneous readings are required, although the time interval may be shortened if desired. But under conditions where a large number of instruments must be read—and this takes from 30 to 60 seconds—it is a distinct advantage to have the slight variations of speed averaged out. In this application the method described has been found to give high accuracy combined with great ruggedness.

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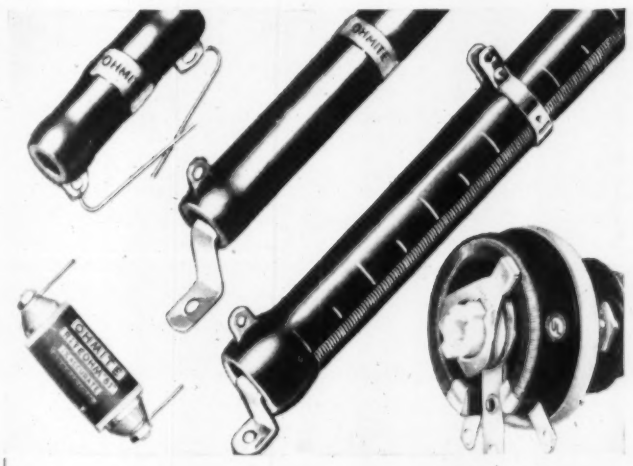

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Awarded an Honorable Mention in the 1940 ("Speeding Up National Defense") Instrumentation Contest

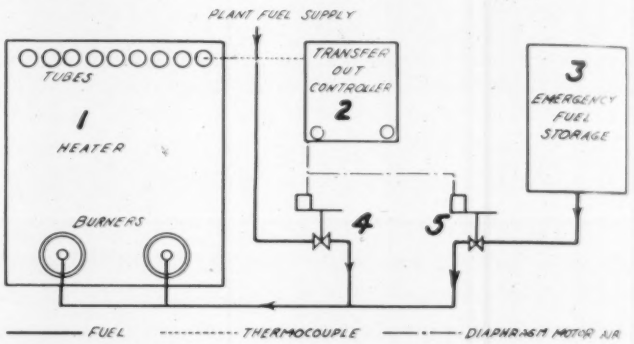
By SELIG H. ISAACS
Instrument Engineer, Wright Aeronautical Corp., Cincinnati, Ohio.

A PROBLEM frequency encountered in industry—and one which has led to much unusual instrumentation—is the maintenance of proper relationships between two different fuels burned in the same firebox. For example let us take the case of a certain plant where a by-product fuel is used as much as possible to satisfy the various processing heat demands. For a number of reasons the available volume of this fuel is highly variable and it has been found necessary to provide an emergency fuel supply to be used at those times when the by-product supply is insufficient. However, the emergency fuel is comparatively expensive and its use must be limited to the absolute minimum.

When it was decided, after a study of fuels, to install automatic temperature control on the material leaving the tubes of a furnace where this emergency fuel supply must be used, it immediately became obvious that some method of cutting the emergency fuel supply into service fully automatically and smoothly, without upsetting the operation of the temperature controller, was of paramount importance. Fig. 1 shows the system which was devised. The thermocouple of the transfer-out temperature controller (Item 2) was installed in the last tube of the heater (Item 1). Diaphragm motor air pressure from the controller was transmitted equally to the control valve (Item 4) which throttles the by-product fuel supply and control valve (Item 5) which throttles the emergency fuel supply. Both valves were equipped with valve positioners.

The temperature controller 2 is one which delivers diaphragm motor pressure from 0 to 15 lbs./in.^{2}, the range which has become standard in throttling control. However, the valve positioners were adjusted in such a manner that instead of moving the valve from shut to open in a 15-lb. range they open the valve wide in an 8-lb. range. Thus valve 4 moves from shut to open when the operating pressure from the instrument changes from 0 to 8 lbs. While the control pressure is below 7 lbs./in.^{2}, valve 5 is shut, but as soon as the pressure exceeds 7 lbs., valve 5 begins to open and it is wide open at 15 lbs. From 8 to 15 lbs., valve 4 remains wide open. Adjusting the positioner to give this type of operation is easily carried out and it requires no change in the standard construction of either the valve or the positioner.

In operation the control system works as follows: As long as there is plenty of by-product fuel, controller 2 is operating below 7-lb. diaphragm motor pressure and valve 5 remains shut. As soon as the plant fuel supply begins to fall the temperature of the material leaving the heater begins to fall and the controller begins to raise the diaphragm motor pressure. As soon as this pressure exceeds 7 lbs., valve 5 begins to open and emergency fuel is fed to the furnace smoothly, accurately, and at a minimum, since valve 4 remains wide open and all available plant fuel is still used.



This system is fully general in that either two liquid fuels or two gaseous fuels, or a liquid and a gas, can be handled—of course assuming proper calculation of valve sizes. In Fig. 1 two burners are shown and the two fuels are shown as mixing as soon as possible. Neither of these conditions is fundamental, as any number of burners can be used, the two fuels can be burned in the same or in separate burners equally well and mixture in a two-fuel burner can take place at any point up to the burner orifices themselves.

This system might further be improved under certain conditions by having the diaphragm motor pressure of controller 2 reset the control point of a flow controller which would in turn operate valves 4 and 5. Thus changes in rate of flow of plant fuel would be compensated for by the flow controller before they could cause temperature upsets. This could only be applied when both the by-product and emergency fuel were in the same physical state (that is, either both liquids or both gases) and when the two fuels were of almost the same heating value.

Two-meter Open-hearth Combustion Control

Awarded an Honorable Mention in the 1940 ("Speeding Up National Defense") Instrumentation Contest

By H. E. HOLLING
Fuel Engineer, Keystone Steel & Wire Co., Peoria, Ill.

THERE arose the need of an instrument that would show the operators of our 150-ton open-hearth furnace when the gas and air mixture was correct for most economical operation of the furnace. The instrument had to be accurate and easily read to enable the operators to derive full benefit from it. At the time this equipment was needed, there was no standard instrument available.

This furnace is fired with natural gas and the combustion air is delivered by a fan type blower. Automatic combustion control could not be used because at various times during furnace operation it is necessary to vary the flow of air to the furnace beyond the point of perfect combustion for the amount of gas being burned in the furnace. The reason is as follows: often the scrap charged to the furnace contains large amounts of oil, especially when charging bundled machine shop cuttings. At times like this it takes a large increase of air to make up the air required for perfect combustion of the gas and oil. Also quite fequently the furnace will become too hot and it is necessary to cut the gas down and leave the air on to cool the furnace rapidly so there will be no damage to the furnace. (The steel, being covered by its slag blanket, does not cool appreciably while cooling the furnace in this manner.)

It was decided that a recorder was required with two pens on the same chart, one pen to represent the air flow and the other pen to represent the gas flow, and the pen travels to be so related that when at any point on the chart the pens were together the air flow would be ten times that of the gas flow which theoretically would give perfect combusion.

In coöperation with a meter manufacturer this was worked out as follows: a standard 5" differential flowmeter

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The pointer of the pyrometer carries a vane. Two similar condenser vanes are attached to the arm of the adjustable target. When the pyrometer pointer reaches the target setting, the pointer vane passes between the condenser vanes and causes a change in the capacity of the circuit which in turn actuates the switch controlling the heating current or fuel valve. A red eye tells whether the heat is on or off.

With no motors, contacts, depressor bars, there is no time lag in response and the utmost in ruggedness and durability is provided. *Write for bulletin No. 3197-A*

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for gauges, instrument panels, etc.

A quick opening Cock, embodying the Nordstrom lubrication principle. This is a convenient and safe valve for use as a try cock or test cock on any line; also for use as a bleeder and as a gauge connection on lines, level indicators and with control instruments. Widely used as a gauge shut-off behind panel boards. Quarter turn opens or closes. Round opening. Body made of forged steel; plug is Stainless steel.

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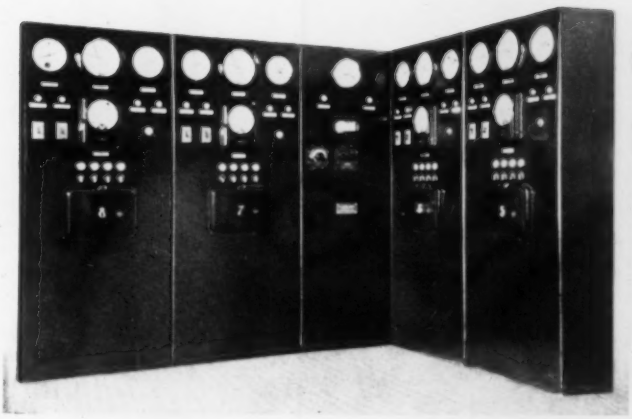

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Ask local Aerovox jobber to show you the L-C Checker. Ask for descriptive literature. Or write direct to . . .

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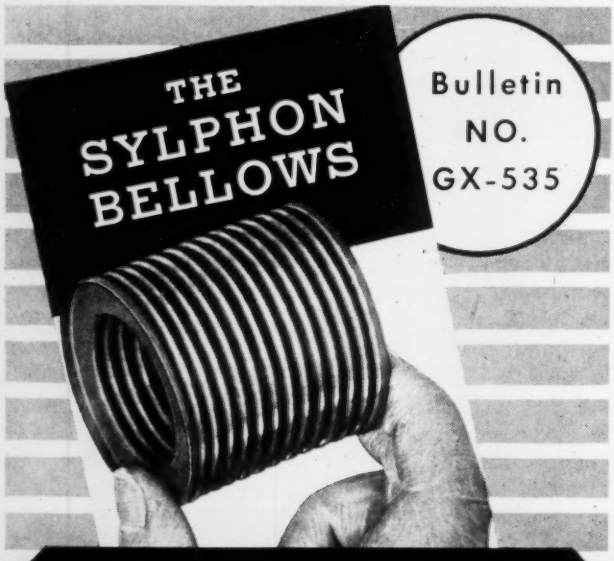


The Answer to your Design Problem may be in this New Bulletin

Write for your copy

THE FULTON SYLPHON CO., *Knoxville, Tenn.*

was combined with a standard 50" flowmeter. The orifices and orifice runs were calculated, so that, on whatever range of the chart the pens were, if they were together, the ratio of air to gas was 10 to 1.

The air and gas valves being independently operated, the furnace operator can make his own decisions as to whether he wishes an excess or defficiency of air in the furnace and by referring to his two-pen meter can have the correct ratio when he desires it. The chart divisions are such that each division the air pen is away from the gas pen represents about ½% of O_2 in the flue gas. Thus a glance at the recorder will tell roughly the gas analysis, since the analysis is known when the pens are together.

The only drawback to this layout is that if air leaks develop in the checker chambers or in the connecting air ducts (all of which are between the air orifice and the furnace) there will be an error in the results varying with the size of the leak. To provide against this condition, flue gas analyses are taken once each day by means of an Orsat. If the analysis does not show the correct results when the gas and air valves are set so that the pens are together on the meter, a thorough inspection is made. Any leaks found are repaired, after which an analysis is again taken to be sure that all of the leaks have been located.

This duplex instrument has been in service for four years and its use has resulted in substantial savings. It is dependable. It is dependable and—unlike many open-hearth instruments—it is used by the operators.

Multi-range Rheostat with Rotating Dial

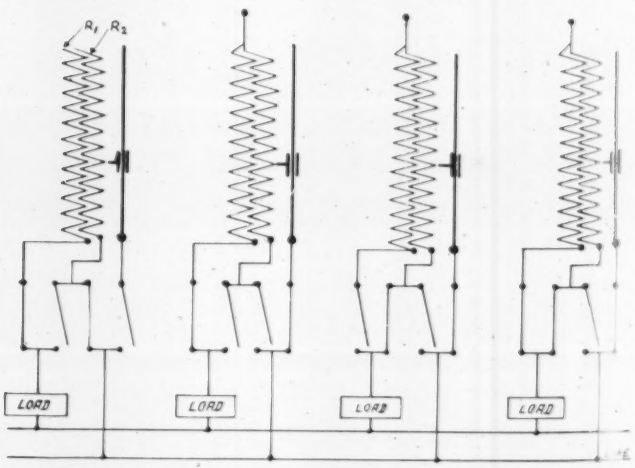
Awarded an Honorable Mention in the 1940 ("Speeding Up National Defense") Instrumentation Contest

By ROBERT ABRAHAMSON
Rex Rheostat Co., New York City

IN nearly all fields of research, educational and production work, a keen demand for the use of regulating devices which provide a greater range than heretofore possible has been emphatically stressed. Futhermore, it is desirable to recognize the ohmic value in the circuit at any moment.

The writer has constructed a tubular slide-wire rheostat which possesses these features and advantages: one unit incorporating four different ohmic resistance values with the corresponding different current capacities.

The resistance carrier of this rheostat has two bifilar wound windings equally distributed over the whole area of the carrier, so that the turn of one winding runs between the turns of the other winding. Both windings—operated by only one slider—are of two wires of identical diameter made of materials having different resistivities, for in-



R_1+R_2 in series FIG.1 — R_1 single FIG.2 — R_2 single FIG.3 — R_1+R_2 parallel FIG.4

nickel-copper and nickel-chrome alloy. Both wires are insulated with a double layer of heat-resistant Fiberglas of high dielectric strength at temperatures reached when the rheostat is fully loaded.

As shown in Figs. 1-4, the ends of both windings and the sliding bar are brought to a four-position switch. The following connections are made possible by this switch:

1. Both windings are connected in series:
2. The nickel-chrome winding is connected:
3. The nickel-copper winding is connected:
4. Both windings are connected in parallel.

For example, a rheostat rated for a wattage of 350 watts and wound with the two windings of 31 ohms in the nickel-copper circuit and 62 ohms in the nickel-chrome circuit, would give the following:

Fig. 1. Both windings in series:
$R = 93$ ohms ; $I = \sqrt{350/93} = 1.95$ amp.
Fig. 2. The nickel-chrome winding:
$R = 62$ ohms ; $I = \sqrt{350/62} = 2.4$ amp.
Fig. 3. The copper-nickel winding:
$R = 31$ ohms ; $I = \sqrt{350/31} = 3.4$ amp.
Fig. 4. Both windings parallel:
$R = 16.7$ ohms ; $I = \sqrt{350/16.7} = 4.1$ amp.

As both windings are equally distributed over the entire surface of the porcelain tube, the rheostat reaches the identical final temperature in each of the four different connections if loaded with the same wattage.

To make it possible to recognize the ohmic value and the allotted load, the shaft of the four-position switch is connected with a square rod—turnable and mounted along side of the rheostat—carrying on each side a scale calibrated in ohms and marked with the maximum load according to the chosen range.

It is especially advantageous to be able to switch from one range to another without changing any connection. Operation of this rheostat is time-saving, gives security to the user and takes the place of four different rheostats.

Since this rheostat is calibrated it is necessary to prevent any deterioration of the resistance wire which might change the ohmic value. Therefore, I have constructed a graphite-lubricated contact brush, which consists of laminated bronze blades. A graphite carbon is inserted in this metal brush to lubricate the sliding path. I have tested this by moving the slider 3000 times on a rheostat of 1000 ohms after which there was no measurable change of ohmic value. Therefore, a rheostat of this construction is also a highly accurate element for any kind of research work.

Averting Several Weeks' Delay in Starting Up New Defense Plant

Awarded an Honorable Mention in the 1940 ("Speeding Up National Defense") Instrumentation Contest

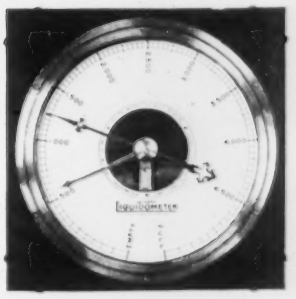
By JAMES L. WATSON

Station Tester, Portland General Electric Co., Portland, Ore.

ABOUT September tenth, a remote metering problem was presented for immediate solution. Bonneville was delivering power to the Portland General Electric Co. at St. Johns through two oil switches and West Salem through one. The St. Johns load was about 50,000 kw. and the Salem load was 10,000 kw., the former swinging ten to twenty thousand and the latter steady. An aluminum reducing plant load was put on Bonneville that week, and the swings on St. Johns could not be handled by their 80,000-kw. capacity, so it was desired that the system swings be thrown onto the P.G.E. Co's steam plant.

The steam plant was equipped with a Leeds & Northrup load controller, but not with a remote meter from St. Johns. In tagged stock was a Westinghouse Type R recording a-c. voltmeter with a range of 90 to 150 volts. The stationary coils of its Kelvin balance were replaced by five-ampere coils, and the moving coils separated, each in series with

Accurate TANK GAUGES for Every STORED LIQUID



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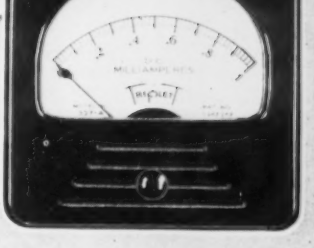

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MODEL 327-A
Model 327-A—One of Triplett's 22 panel instrument case styles. These precision electrical measuring instruments are provided in round, square, fan and twin cases—2", 3", 4", 5", 6" and 7". A complete line of portable instruments for exacting measurements also is offered.
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Continued use of the Eppley Standard Cell by the leading American manufacturers of instruments is adequate testimony to their dependability and excellence

EPLAB
THE EPPLEY LABORATORY, INC.
SCIENTIFIC INSTRUMENTS
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U.S.A.

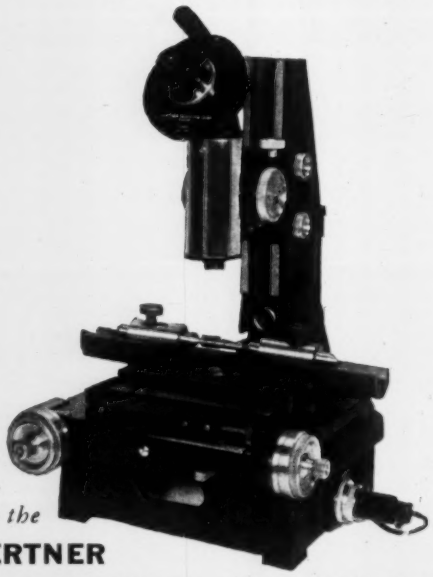
suitable resistance for 100 volts. The current coils of top were connected to 60/1 current transformers in the bushings of one oil switch and the bottom ones to similar current transformers in the other switch. The moving coils were connected across secondaries of 600/1 potential transformers, across the 57,000-volt bus, thus totaling the load on the two oil switches. The torsion spring was adjusted to give 75 megawatts (75,000 kw.) full scale.

The pen-driving worm shaft was extended through the glass case to the right ten inches and a Micarta drum mounted thereon to carry a slide wire of 160 ohms and long enough for the slide to go full length with full pen travel. Two hundred twenty millamps. were put through the wire from the St. Johns station battery by means of silver slip rings and silver brushes. A small silver wheel on a countershaft served as a slide. The external circuit was taken from the zero end of the slide wire and the wheel shaft, through an adjustable resistance, and 1400 ohms of leased telephone cable wires to the Leeds & Northrup automatic regulator, an indicator on the steam plant board and another on the Load Dispatcher's board. The current in the external circuit was adjusted to 20 millamp. full scale or 75 megawatts. The load regulator was 31.25 mv. full scale or 30 megawatts, so a resistance of 1.5625 ohms was placed in series with the external circuit and the load regulator galvanometer connected across it, in series with a 50-ohm loading resistance. This made a scale constant of 2.5 on the regulator.

The steam plant indicator was made of an old G. E. type D3 millivoltmeter which was 20 milliamps. full scale. The Load Dispatcher's indicator was a similar 8-milliamp. instrument, so enough shunt was put on it to make it also 20 ma. full scale, the new scales of course being 0 to 75 megawatts.

This job took three men four days as compared with several weeks to get a factory job, and has worked fine. The fluctuation on St. Johns now is seldom over three or four megawatts.

Increase . . . **PRODUCTION**
Speed-Up . . . **MEASUREMENT**



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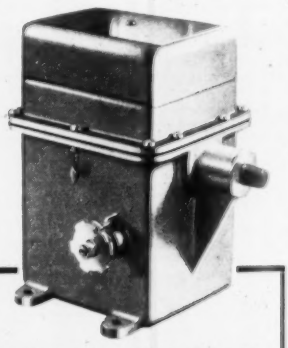

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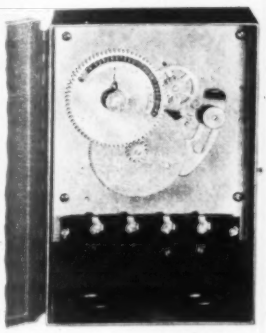

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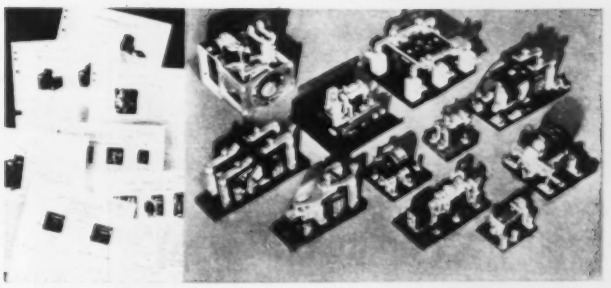

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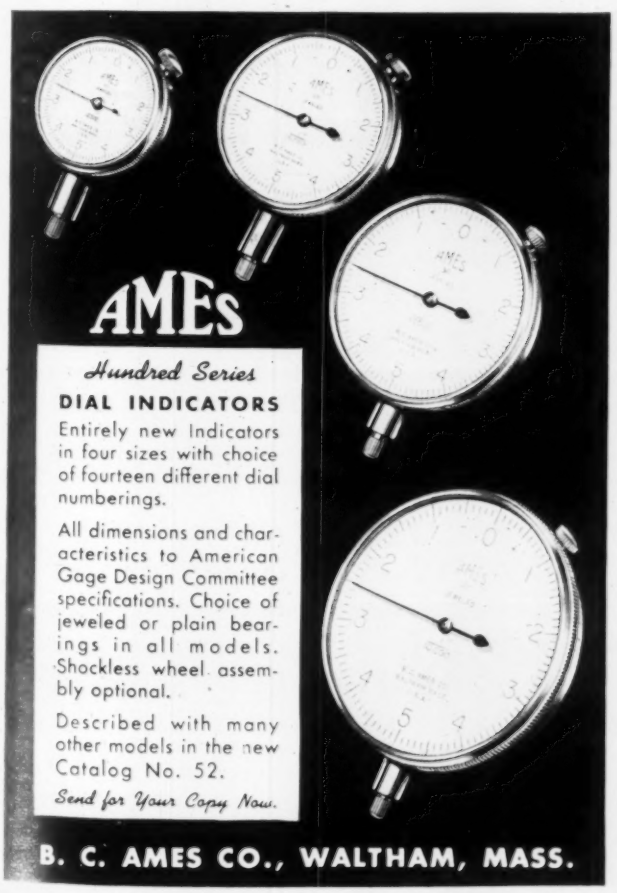

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INSTRUMENTS' BOOK SHELF

Flash! Seeing the Unseen by Ultra-high-speed Photography. By HAROLD E. EDGERTON and JAMES R. KILLIAN, JR. Hale, Cushman & Flint, Boston, 1940. Cloth, $8\frac{1}{4}$ · $11\frac{1}{4}$ inches, vii + 203 pages. Price $3.00.

More than two hundred and fifty photographs, many of them taken in a millionth of a second, the subjects ranging from the flight of a bumblebee to the flight of a weaving shuttle, from the propagation of cracks in glass to the progressive deformation of a golf ball, from biology to industry, from sports to science—these constitute the principal "contents" of the volume under review. To be adequate, a review should not be strictly verbal: it should include at least one "sample." But the best samples are the full-page pictures. So that's out. Moreover, there is no "representative" sample in such a varied collection. The designer of the volume's jacket used eight photographs.

Another reason for the inadequacy of words is that "photograph" and "picture" convey weak meanings. There is needed a word suggesting the extremely small in time—like "micrograph" which refers to the extremely small in space. The word INSTAGRAPH readily comes to mind—so readily that the reviewer may have seen it, though he doesn't remember.

Then, too, only a gifted poet could sing the entrancing beauty and startling novelty of the subjects. As Killian explains in his introduction: "As a craftsman Dr. Edgerton is interested not only in facts and analyses but in obtaining a record that presents these facts and analyses in a manner that pleases him. Many times, as in his studies of splashes, he has taken definitive pictures only to discard them because he sought a description that was eloquent as well as lucid. . . As an artist does, he has sought to establish the best possible correlation between meaning and expression."

One result of Dr. Edgerton's devotion is a galaxy of individually delectable and collectively magnificent instagraphs. He himself did not take them all, but he has endowed with esthetic unity a multiform collection, so that it is not an assemblage but an assembly.

A further result of Dr. Edgerton's artistry is the enhancement of the scientific and technical value of this volume—yes, of its practical value to industry.

As to the text, it is so brief that the volume is an album rather than a book. The text, after a fourteen-page introduction, consists largely of specific explanations and commentaries. Though necessarily discontinuous, it is so elegantly written that it "sounds"—rather than "reads"—like the unobtrusive remarks of a cultured lecturer showing lantern slides. Because this text is unobtrusive and well-written, the best way to enjoy this work of Edgerton and Killian is to open it at Page One and savor it slowly, page by page, instagraph by instagraph, as you would sit back and enjoy an illustrated lecture by Harlow Shapley . . . or whoever *your* hero of the scientific lecture platform may be.

Speaking of hero-worship, that of Mr. Killian for Professor Edgerton, while perfectly justified, is expressed with what seems to us the wrong emphasis. Mr. Killian in his introduction traces the history of stroboscopes, going into fascinating details about the nineteenth-century instruments and the personalities of their inventors, then giving fewer and fewer details as he comes to modern times and finally giving the impression that what is now known as the Edgerton *type* of stroboscope suddenly sprang full-armed like Pallas Athene from the brain of his Zeus. Actually, stroboscopes utilizing millionths-of-a-second capacitor discharges through vapor lamps were on the market in the nineteen-twenties. As a rule, the inexpensive instruments did not quite satisfy the increasingly exacting requirements of science and industry; and the ones that "had everything but the kitchen sink" cost about thirty thousand francs plus a few hundred dollars to Uncle Sam (because they were imported from France), plus fat fees to experts. The historic fact is that Edgerton is to the flash-tube stroboscope what Fulton is to the steamboat: not the inventor but the fellow who made the darn thing work for the good of mankind. If hero-worshipper Killian looks up old files of *Instruments* he will be able to augment his documentation—and to improve subsequent editions of this otherwise flawless volume by avoiding giving offense to the pioneer inventors and *their* hero-worshippers.

Subsequent editions there must be, because Edgerton and his co-workers Germeshausen and Grier have rendered an outstanding service to science and industry—and to art—by perfecting the flash type of stroboscope and developing the technique of its use. This volume should be followed not only by several "albums" of instagraphs with brief captions, but also by a technical "book." The need for albums and books is beginning to be felt. The present volume marks the birth of a distinct occupational field—a new profession, a new business, a new industry, a new art—as did the early cinematograph shows in 1895, as did the early voice broadcasts in 1920. This new field may not grow as big as motion pictures or as radio, but certainly the handful of workers at M.I.T. will obey biology: it will divide, differentiate and grow into groups of professionals and of amateurs, of artists and of engineers, of business executives and of customers. There will be societies, magazines, college courses, and all the panoply of a recognized field of human activity.

That, Mr. Killian, is your master's just claim to immortality. That is why a type of instrument which was on the market before he began his work will forever be known as the Edgerton Stroboscope. That is why it is a pleasure to hail this volume as a source of inspiration and recommend it wholeheartedly to all *Instruments* readers.

—M. F. Behr

Re: Books on Instrument Servicing

A SUBSCRIBER WROTE:

In your February editorial you implied that would-be authors of notes on instrument servicing should consult you as to the uncovered fields. I am deeply interested in adding a few words to the many well-written ones that I read each month when *Instruments* comes via the mail.

Can you please list a few of the instruments that apparently need service notes written? We service quite a variety. . . .

April 2, 1941 H. S. F.

OUR REPLY:

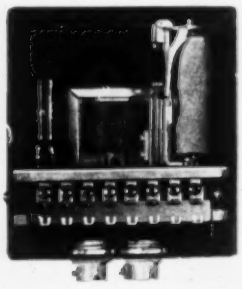
Thank you for your letter of April 2nd. As I stated in my February editorial, we are about to publish a series of articles on servicing *electrical* instruments; and these articles will later be issued in the form of a book. The field of *aircraft* instruments, likewise, is taken care of—not by us but by others. This also applies to that branch of instrument servicing which is so similar to *watch and clock servicing* that the excellent books on that field can be used profitably.

There remains, then, the large field of *non-electrical industrial* instruments. This is not a one-man job. . . . There is disagreement over the terms "care," "maintenance," etc., as discussed in my March editorial.

There are a number of men like you who have had actual experience in maintaining and servicing several types of instruments. . . . The only practical thing to do is to have you and the other men write about the several topics in which each has had long experience—and concerning which each is able to write authoritatively and instructively.

Division of topics need not be by types of instruments; it may be by types of work. For example, one man might be this country's outstanding authority on the servicing of non-metallic diaphragm instrument elements, from the most delicate draft gage element employing gold beater's skin to the most rugged control-valve diaphragms. Another man might have made himself into the highest authority on bearings which should be nearly frictionless and yet pressure-tight, such as are found in many flowmeters, liquid-level instrumentation, etc. . . .

Select some particular topic (whether it be a type of instrument or a type of work) in which you know that you have made yourself an authority; and *send us an outline of the article which you propose to write.* (If your proposed treatment is longer than four thousand words, it would not be one article but two or three.)



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3 As a pressureless limit switch with maintained accuracy and long life.

MANUFACTURERS' NEW LITERATURE

In this department we report ALL pieces of NEW literature pertaining to Instrumentation, received from the manufacturers. Readers may secure without cost (unless noted) any or all items reported here, by filling out and mailing the coupon.

1-121 **Time Controls.** Binder of 9 bulletins, 8½" × 11", describes and illustrates manual and automatic reset interval timers, time delay relays, time switches, program clocks and timers, weather control and magnetic contactors, electrically and mechanically held. Paragon Electric Co., 37 W. Van Buren St., Chicago, Ill.

1-122 **Gages and Dial Indicators.** Catalog No. 52, 8½" × 11", 40 pages, describes and illustrates a number of dial indicator models, dial micrometers, thickness measures, upright gages and cylinder gages. B. C. Ames Co., Waltham, Mass.

1-123 **Universal Photometer.** Folder, 8½" × 11", 8 pages, covers in particular the use of the "Photrix" photometer for measuring the density of negatives and the evaluation of these density measurements for determining exposure time in contact printing and enlarging as well as for ballancing of three-color separation negatives. Intercontinental Marketing Corp., 8 West 40th St., New York City.

1-124 **Thermostat.** Form 63, 8½" × 11", 4 pages, describes the Positrol thermostat for control of electrically heated appliances and devices. General Thermostat Co., 389 E. 165th St., New York City.

1-125 **Weigh Spoon.** Pamphlet, 3¾" × 8⅝", 1 page, describes and illustrates small hand scale for measuring chemicals for laboratory use of chromium plated brass construction. Spoon is dipped into chemical and suspended from the hand on a chain. Counter balance built into the handle is adjusted for weighing from ½ gram to 10 grams. Aetna, Inc., 205 E. 42nd St., New York City.

1-126 **Precision Electrical Instruments.** Catalog 1-21, 8½" × 11", 4 pages, describes and illustrates single or multi-fange meters, dual or cross pointer movements with chrome, alnico or cobalt magnets and featuring long open faced linear metal scales with easy to read numerals and non-glare background. De-Jur-Amsco Corp., Shelton, Conn.

1-127 **Automatic Solution Control.** Bulletin, 8½" × 11", 2 pages, covers Type RE, Solu-Bridge controller which indicates concentration of a solution in percentage, parts per million or other terms, operates a visual or audible warning, or controls a valve or other corrective means when concentration exceeds or falls below set limit. Industrial Instruments Inc., 156 Culver Ave., Jersey City, N. J.

1-128 **Submersion Thermoswitch.** Bulletin, 8⅜" × 11", 2 pages, describes and illustrates water-proof and vapor-proof thermoswitch with a hermetic seal for the adjusting screw and a water tight conduit for the leads. Fenwal Inc., Ashland, Mass.

1-129 **"Ultrasonics" — The Science of High-Frequency Sound Waves.** Bulletin 92, 9" × 11½", 10 pages, discusses this science and gives descriptions of four "Ultrason" units. Televiso Products, Inc., 2300 N. Sheffield Ave., Chicago, Ill.

1-130 **High Temperature Furnaces.** Catalog F-241, 7⅜" × 8½", 32 pages, describes and illustrates box, muffle, pit and tube type furnaces and automatic control instruments for high temperature furnaces and high temperature combustion tubes, pyrometers, tap transformers, etc. Burrell Technical Supply Co., 1935 Fifth Ave., Pittsburgh, Pa.

1-131 **Throttling Control.** Bulletin No. 70, 8½" × 11", 4 pages, describes and illustrates instrument which, operating in conjunction with a standard pyrometer controller automatically throttles heat input of gas and oil fired heating equipment. Lindberg Engineering Co., 221 N. Ludlin St., Chicago, Ill.

1-132 **Fineness Meter.** Folder, 6" × 9", 4 pages, covers instrument for obtaining surface areas of finely ground powders. Meter consists essentially of two manometers, a permeability cell and a calibrated capillary. Bowen & Co., Inc., 4708 Bethesda Ave., Bethesda, Md.

1-133 **"The Ohmite News."** March 1941 issue, 2 pages, discusses Sir Humphry Davy and his work in electro-chemistry and includes among other items a method of using the Ohm's Law calculator to find parallel resistance. Ohmite Mfg. Co., 4835 Flournoy St., Chicago, Ill.

1-134 **Photoelectric Fluorescence Meter.** Bulletin, 8½" × 11", 4 pages, describes and illustrates the Lumetron meter for fluorescence, transmission and reflection measurements. Photovolt Corp., 10 E. 40th St., New York City.

1-135 **Calculating Time Recorder.** Catalog, 8½" × 11", 12 pages, describes and illustrates various models of the Calculagraph which calculates and records elapsed time in hours and minutes or hours and tenths on operations for 12 hours or less or up to 60 hours. Calculagraph Co., 50 Church St., New York City.

1-136 **Potentiometer and CO_2 Recorders.** Folder (N-16046), 7¼" × 10⅝", 8 pages, gives characteristics and applications of Micromax recorders, new daily-tear-off device for easy filing of strip-charts shown, also full size record drawn by a temperature recorder. Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia, Pa.

1-137 **General Radio "Experimenter."** March 1941, 8 pages, contains two articles entitled "Transmitter Maintenance in the Modern Broadcasting Station" and "Calibrating Three-Phase Power-Factor Meters with the Variac." General Radio Co., 30 State St., Cambridge, Mass.

1-138 **Rheostats and Potentiometers.** Bulletin, 8½" × 11", 6 pages, describes and illustrates heavy duty rheostats and potentiometers for applications in spot welding, mixing panels, motor control, electronic devices, radio transmitters, dynamo voltage control, portable power amplifiers, primary power circuits, electroplating and laboratory work. DeJur-Amsco Corp., Shelton, Conn.

1-139 **"Solving Industrial Crimes."** No. 26, 4" × 5½", 16 pages, is devoted to listing of applications of maker's recording instruments to detect and correct loss of time and power and improve operation. The Esterline-Angus Co., Inc., Indianapolis, Ind.

1-140 **Thermometers.** Catalog 4000, 8½" × 11", 72 pages, describes and illustrates complete line of glass, dial and recording thermometers and accessories including price list. Also listed are industrial glass thermometer applications. Manning, Maxwell & Moore, Inc., Bridgeport, Conn.

1-141 **Process-Cycle Controllers.** Bulletin 557, 8¼" × 11¾", 4 pages, gives characteristics and advantages of coordinated process control system. The Bristol Co., Waterbury, Conn.

1-142 **Precision, Laboratory and Maintenance Instruments.** 1941 Catalog, 8½" × 11", 24 pages, covers signal generators, tube tester, capacity-resistance bridge, meters and laboratory accessories, cathode-ray oscillograph and accessories, beat frequency audio oscillators and transmission measuring set. The Clough-Brengle Co., 5501 Broadway, Chicago, Ill.

1-143 **Deep Immersion Thermocouple for Molten Glass.** Bulletin No. 22-31, 8¼" × 11½", 8 pages, describes and illustrates thermocouple primarily designed for feeders but also of value in measuring any molten glass temperature. May be used in a glass feeder or in a glass pot or tank. Brown Instrument Co., Wayne & Roberts Aves., Philadelphia, Pa.

1-144 **Dial Indicators.** Bulletin, 8½" × 11", 2 pages, announces new hundred series indicators in four sizes, fourteen different dial numberings indicating tenths of thousandths, half-thousandths and thousandths of an inch or thousandths and hundredths millimeters, includes dimensions of indicators. B. C. Ames Co., Waltham, Mass.

1-145 **Running Time Meters.** Bulletin F-1, 8½" × 11", 2 pages, describes and illustrates synchronous motor driven running time meters designed for use on a-c. circuits to automatically and cumulatively register the total operating time or idle time of any circuit, machine or system. The R. W. Cramer Co., Inc., Centerbrook, Conn.

1-146 **Polyphase Motors.** Bulletin GEA-1974B, 8" × 10½", 4 pages, gives construction, ratings and applications of FHP motors, Type K ¼—¾ h.p. General Electric Co., Schenectady, N. Y.

1-147 **Boiler Water Concentration Control.** Bulletin, 8½" × 11", 6 pages, describes and illustrates continuous blow-down system consisting of a flow indicator, blowdown meter, proportioning valve, high temperature heat exchanger, low temperature heat exchanger and sometimes a flash tank. Henszey Co., Watertown, Wis.

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1-148 **Test Set.** Catalogue 1606-E, 8½" × 11", 8 pages, describes and illustrates portable line-testing device and telephone for maintenance of communication and signalling systems. Automatic Electric Co., 1027 W. Van Buren St., Chicago, Ill.

1-149 **Air Compressors.** Bulletin H-621-B5B, 8" × 10½", 6 pages, describes and illustrates vertical single-cylinder, single-stage Type VS compressors equipped with Worthington feather valves. Worthington Pump & Machinery Corp., Harrison, N. J.

1-150 **Photoelectric Relay.** Bulletin GEA-3533, 8" × 10½", 4 pages, announces relay for counting, diverting, controlling, signalling, limiting and protecting, shows line of photoelectric accessories. General Electric Co., Schenectady, N. Y.

1-151 **Control Instruments.** Bulletin No. Z4000, 8½" × 11", 12 pages, describes and illustrates remote controllers and auxiliaries, indicating pyrometer controllers and heating and cooling temperature time cycle controllers; also radiation leads and thermocouples and lead wire. Wheelco Instruments Co., 1933 S. Halsted St., Chicago, Ill.

1-152 **Strain Gages.** Booklet, 5¼" × 7¾", 16 pages, covers strain gages for measuring deformations in material under strain and accessories, extensible strain gage for measuring differences of deformation in machining on large castings, etc., 2" extensometer for laboratory use, strain gage calibrator and centrifuges. E. F. Metzer & Son, 2600 North 6th St., Philadelphia, Pa.

1-153 **Laboratory Instruments.** Catalog No. XU41, 8½" × 11", 184 pages, describes and illustrates complete line of chemical and biological apparatus. American Instrument Co., 8010 Georgia Ave., Silver Spring, Md.

1-154 **Aerovox "Research Worker."** Vol. 12, Nos. 11 & 12, 4 pages each, contains respectively, articles entitled "Theory and Operation of Multivibrators" and "Obtaining Precise Audio Frequencies." Aerovox Corp., New Bedford, Mass.

1-155 **Plug-In Tube-Type Resistor Replacement Manual.** Fourth Edition, 8½" × 11", 40 pages, contains all previous listings covering existing set replacements, together with many new listings bringing the data squarely up-to-date. Price of this catalog is 15 cents. Requests must be sent direct to Clarostat or local jobber and cannot be sent from this office. Clarostat Mfg. Co., Inc., 285-7 North 6th St., Brooklyn, N. Y.

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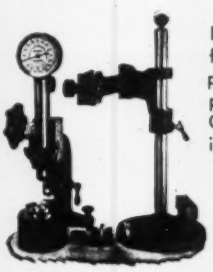

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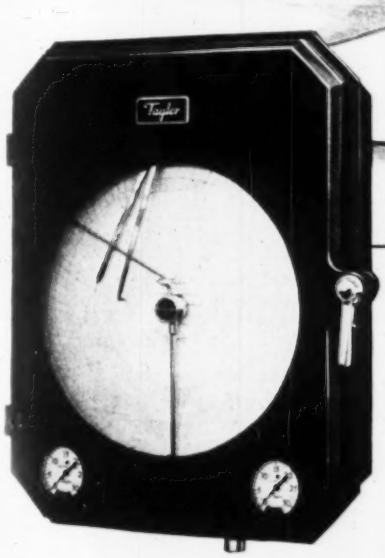

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